REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From – To)
30 May 2002	Workshop Proceedings	26-28 February 2002

4. TITLE AND SUBTITLE

Tackling the Space Community's Analytical Challenges Workshop Report

5a. CONTRACT NUMBER
N00014-99-C-0113

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)

Lt Col Suzanne M. Beers
Corrina Ross-Witkowski, Editor/Publisher

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Military Operations Research Society, 1703 N. Beauregard St, Suite 450, Alexandria, VA 22311

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution Statement A:
Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This publication is the report of the Tackling the Space Community's Analytical Challenges Workshop.

15. SUBJECT TERMS

16. SECURITY CLASSIFCATION: UNCLASSIFIED			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Corrina Ross-Witkowski
a. REPORT	b. ABSTRACT	c. THIS PAGE	Unlimited	1-36 and Appendix A-B	19b. TELEPHONE NUMBER (include area code)
Unclassified	Unclassified	Unclassified			703-933-9070 FAX: 703-933-9066

Standard Form 298 (Rev. 8-

20030310 043 AQM03-05-1166

Prescribed by ANSI Std. 239-18
298-102

CLASSIFIED BY:
DECLASSIFIED ON:

SECURITY CLASSIFICATION OF THIS PAGE

MILITARY OPERATIONS RESEARCH SOCIETY

Tackling the Space Community's Analytical Challenges Workshop Report

26-28 February 2002
Colorado Springs, CO

Chair: Col T.S. Kelso
Technical Chair: Lt Col Suzanne M. Beers

UNCLASSIFIED
Approved for Public Release

1703 N. Beauregard Street ♦ Suite 450 ♦ Alexandria Virginia 22311-1717
(703) 933-9070 ♦ FAX: (703) 933-9066 ♦ email: morsoffice@aol.com
URL: http://www.mors.org

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Introduction and Workshop Purpose

United States Space Command combines Air Force, Army and Navy space components to provide space-based support and combat capabilities to the warfighting Commanders-in-Chief (CINCs). The support is currently focused predominantly in the areas of communication, navigation, meteorology, surveillance and reconnaissance. Although no current combat capabilities are provided directly from space, the future is ripe to exploit space for "gaining and maintaining the high ground." Some of the current combat capabilities being explored by the space community are space based radar and laser platforms, common aerodynamic vehicles and conventional ballistic missiles that would carry various payloads in and through space for precision strike. These current and future capabilities would benefit from a broad range of analytical support, defining the associated doctrine, exploring relevant tactics, comparing operational concepts, and assuring sustainment over the lifetime of the envisioned systems. The MORS Workshop "Tackling the Space Community's Analytical Challenges" focused a select group of analysts and decision makers to help define these space community challenges; survey current approaches, methodologies, models, tools and databases; identify gaps in the existing analytic capabilities; and, propose workable solutions to fill these gaps and support the needs of the warfighter.

USSPACECOM and the services' space components are key elements of the nation's military force structure. The Space Commission, the military's scientific advisory communities, and a number of independent study groups have suggested increased emphasis and investment in space capabilities. To ensure current capabilities are appropriately leveraged as well as to help provide a framework for any future changes, the analytic community should be prepared to help answer a broad array of questions unique to this community. These questions include:

Analytical Methods. What methods and approaches are available to quantify the benefits space offers to CINCs conducting a broad array of operational missions? Stated differently, what does space bring to the fight?

- How can the benefits of the *information* provided by space systems such as unimpeded communication, precision navigation, and near-real time global weather forecasts be quantified in theater or campaign-level analysis.
- What are the unique contributions of space systems? How can the benefits of *missions* provided or supported from space be quantified and balanced or traded against those same missions performed by terrestrial or airborne platforms?

Analytical Tools. How can analytical tools be updated to include valid representations of space systems, together with their contributions and limitations?

- The analysis community's models and simulations have grown around the commonly accepted definitions of attrition warfare. Space capabilities' modeling has for the most part been limited to astrodynamic code or models that address specific space-related topics, such as navigation jamming. What is the best approach to developing models that will capture the unique capabilities and limitations of space-based systems? Should a new set of space-focused Lanchester equations be developed? Should current models be

linked together to form system-to-engagement-to-theater-to-campaign analysis capabilities?

Operational Methods. Whereas many of the operations of military units are well defined and steeped in traditions, those of the space components are evolving and are in the early stages of development. Many of the tools that are the norm for the operations research community have not been embraced within the space operations community.

- Scheduling optimization methods. The scheduling of a worldwide network of limited resources to meet diverse mission needs (e.g., scheduling time on the antennas comprising the Air Force Satellite Control Network) is currently accomplished manually, using a very time consuming and personnel-intensive method. The scheduling of these ground systems, including meeting prioritized mission requests for satellite command and control contacts, scheduled maintenance periods, software freezes in preparation for launches, etc. is ripe for the application of operations research methods to decrease the personnel requirements and optimize resource scheduling. What specific methods or tools should be recommended to approach this and other similar issues in the space community?

Acquisition and Sustainment Issues. Many of the ground systems associated with space operations are approaching, or have exceeded, their design life and are providing challenges to the maintenance and acquisition communities to sustain the systems in an operational status.

- Failure trending methods and Failure Modes Effects And Cause Analysis (FMECA). The failure modes of space systems' ground equipment are not well understood, documented, analyzed, or predicted. How might methods provided by Failure Trending And FMECA or other methods be applied to these systems to help predict impending failures and more adequately plan for maintenance and upgrade programs?
- Conditioned based maintenance methods. Standard maintenance methods consist of periodic preventative maintenance activities and time-of-need maintenance activities to correct deficiencies and system outages. In many cases, the periodic maintenance activities induce more problems than they cure. Maintenance conducted at the point of failure typically involves mission-impacting down time while the system is repaired and/or while parts are procured. Condition-based maintenance involves developing measurements and associated rule-bases that provide an indication of impending failure modes. What analytic methods could be applied to the space ground system sustainment issues to increase operational availability while decreasing overall life cycle costs?

The workshop was organized into four working groups to tackle these, and similar questions. One hundred and seventeen analysts, engineers and space operators attended the workshop to discuss the challenges and formulate the space analysis way ahead. The working groups were organized to address the challenges outlined above, and were led by the working group chairs/co-chairs identified in Table 1.

Table 1 Workshop Working Group Chairs and Co-Chairs

NAME	PHONE	EMAIL	Position
Col TS Kelso	(719) 554-9801	ts.kelso@peterson.af.mil	Workshop Chair
Lt Col Suzanne Beers	(719) 556-2829	suzanne.beers@cisf.af.mil	Technical Chair
Steve Friedman	(937) 476-2509	steve.friedman@veridian.com	WG 1 Chair
Capt Jeff DelVecchio	(310) 363-0768	Jeffrey.delvecchio@losangeles.af.mil	WG 1 Co-Chair
Mike Garrambone	(937) 476-2516	Mike.garrambone@veridian.com	WG 1 Co-Chair
Steve Pierce	(256) 955-2377	Steve.pierce@smdc.army.mil	WG 1 Co-Chair
Mark Reid	(719) 651-8855	mreid@ara.com	WG 2 Chair
Tom DeLaCruz	(719) 637-6224	Tdelacruz@scitor.com	WG 2 Co-Chair
Dr Steve (Flash) Gordon	(407) 208-5776	Steve.gordon@afams.af.mil	WG 2 Co-Chair
MAJ Bill McLagan	(719) 554-5122	Bill.mclagan@peterson.af.mil	WG 2 Co-Chair
Dr Lee Lehmkuhl	(719) 572-8307	leel@mitre.org	WG 3 Chair
Lt Col Steve Baker	(719) 333-4405	steve.baker@usafa.af.mil	WG 3 Co-Chair
Lt Col Suzanne Beers	(719) 556-2829	suzanne.beers@cisf.af.mil	WG 4 Chair
Maj Brent Barber	(719) 556- 2817	brent.barber@cisf.af.mil	WG 4 Co-Chair
Greg Keethler	(505) 816-6382	gkeethler@ara.com	Synthesis Chair
Col Jerry Diaz	(719) 333-4470	jerry.diaz@usafa.af.mil	Synthesis Co-Chair

Plenary Session

The workshop started on Tuesday morning with a plenary session, where several of the space community's senior leaders availed the attendees with their challenges. Lieutenant General Edward G. Anderson III, US Army, Deputy Commander in Chief, United States Space Command (USSPACECOM) spoke from his perspective as the lead of the joint space warfighting community. General Anderson described the transformation that is underway. It involves integrating space and information capabilities into joint and combined expeditionary forces, in which space and cyber space are core capabilities...enabling decision superiority with timely information. The President has assigned USCINCSPACE responsibility for space and computer network operations, including: (1) providing missile warning for all 50 states; (2) serve as single point for military space operations; (3) military lead for computer network defense and attack; and, (4) requirements development for ballistic missile defense. The computer network operations and space control missions place USSPACECOM in the thick of controlling information flow...better than our adversaries...in order to maintain decision superiority. The operational challenge is to integrate the "vertical" space and information operations capabilities offered by the service components "horizontally" to achieve the combatants' desired protect and deny effects. In order to understand what each of these capabilities brings to the fight, the warfighting CINCs need modeling, simulation and analysis support to quantify and understand space and cyber effects during operational planning. Specifically, they need to be able to quantify the added value of space and computer network operations in joint warfighting and homeland defense. With this understanding, decision making on the impact of future space and CNO force structures, especially during funding priority debates, will be enhanced.

Dr David Finkleman, USSPACECOM's Chief Scientist, amplified the General's comments by describing space's role in the global war on terrorism and USSPACECOM's space analysis strategy and urgent needs. Dr Finkleman discussed the significance of space in current operations...which has gone much farther than the force enhancement demonstrated during

Operation Desert Storm. He argued that the diffuse nature of the terrorist threat demands that long term defense strategy include the global presence of space systems...that space capabilities must be a major element as joint task forces are dispatched. Dr Finkleman echoed General Anderson's call for the ability to quantify the value-added of space mission areas beyond force enhancement, and to assess diverse approaches to mission accomplishment. Further, the analysis community must be able to assist the decision makers in examining distributed surveillance and communications architectures and tailoring them for specific applications; and in showing the economies achieved in terrestrial resources by innovative employment of space capabilities.

Brigadier General Russell Anarde, Director, Plans and Programs, Air Force Space Command spoke from his perspective as the chief planner and programmer for the Air Force's space assets. He echoed Dr Finkleman's assertion that military space operations are evolving from a supporting function to a core capability. As the operations and the force evolve, new challenges and questions for the planners and decision makers arise. Questions like: "What to buy?" "When to employ it?" "How to integrate it into the total force?" Tools and analysis methods are needed across the gamut of decisions being made by the Command and the DoD...joint resource allocation decisions as well as service planning and operation decisions. Decisions like: "What is the value of the space acquisition program compared to investments in air, land and sea combat alternatives?" "How does space contribute to achieving operational objectives?" "What is the most cost-effective mix of air and space assets?" "How will the AF provide space support to the total force?" "What resources are required to implement the Space Commission recommendations?" "What is the military value of space capabilities to current operations?" "What level of space support must be sustained as new combat capabilities are developed?" "Which concepts best support the CINC's objectives and needs?" General Anarde echoed General Anderson's issues put forth by the Space Commission and GAO; especially the lack of tools to aid in understanding of the utility of space-based capabilities in warfare and to articulate space's contributions.

Finally, the last plenary speaker was Colonel David Ifflander, representing United States Army Space Command (ARSPACE). He discussed the Army's need for support to their missions of space operations, missile defense, computer network operations and homeland defense. Colonel Ifflander described how space operations, including space control; communications; position, navigation, and timing; blue force tracking; missile warning; and, intelligence, surveillance and reconnaissance enable the Army Objective Force characteristics of responsiveness, deployability, agility, versatility, lethality, survivability and sustainability. He asserted that a lethal, knowledge-based force enabled through space and information superiority will be dominant across the full spectrum of conflict. In order to achieve this end-state, the Colonel stated the analysis needs of ARSPACE, to include building realistic space play into wargames, exercises, models and simulations in order to educate the Army decision makers and soldiers on the employment of space assets and show the dynamics of space operations' impact on ground forces.

After the plenary session, the attendees broke into four working groups to address the challenges laid out in the workshop objectives...analytical methods, analytical tools, operational methods and sustainment methods...and by the plenary speakers. The remainder of this report describes

the outcome of the working group proceedings...analytical methods, analytical tools, operational methods and sustainment methods.

Working Group 1: Analytical Methods

The US Space Command Vision for 2020 states, "*The increasing reliance of US military forces upon space power combined with the explosive proliferation of global space capabilities makes a space vision essential. ...we must be prepared to exploit the advantages of the space medium.*"

Operation Desert Storm and Operation Enduring Freedom have highlighted the truth in this statement. The high profile success of space systems has demonstrated their operational utility, albeit in a manner that still makes it difficult to accurately quantify. In addition, although significant evidence exists that these systems can alter the outcome of combat, the "sample size" is as of yet still too small to substantively contribute to analytic methods and operations research. It is, therefore, of some importance that techniques and tools be developed and/or refined that can help quantify the operational contributions of space systems.

However, as the Air Force Space Command Strategic Master Plan states, "*Minimal MS&A capabilities exist for quantifying the military value of space systems, particularly mission and campaign warfighting contributions. The current analysis tools primarily support system performance assessments. These performance characteristics do not include battlefield planning and integrated effects with other weapon systems in a wartime environment.*"

With this in mind, WG 1, Analytic Methods, set out to address these issues and answer the questions posed in the Workshop's Terms of Reference (TOR):

- What methods and approaches are available to quantify the benefits space offers to CINCs conducting a broad array of operational missions? Stated differently, what does space bring to the fight?
- How can the benefits of the *information* provided by space systems such as unimpeded communication, precision navigation, and near-real time global weather forecasts be quantified in theater or campaign-level analysis?
- What are the unique contributions of space systems? How can the benefits of *missions* provided or supported from space be quantified and balanced or traded against those same missions performed by terrestrial or airborne platforms?

Objectives

The objectives for WG 1 were straightforward, albeit somewhat ambitious as we soon discovered:

- Identify current analytical methods and approaches and determine suitability for defining space's contribution to the warfighting effort - both at a theater and campaign level.
- Define space system Measures of Performance (MOPs) and Measures of Effectiveness (MOEs) and their linkage into the "standard" Measures of Outcome (MOOs) used by other theater and campaign analyses.

- Identify deficiencies in current methods and determine if new analysis methods (i.e., such as some new form of Lanchester equations) are needed, or simply slight modifications of current methods to address how best to quantify the contributions of space capabilities to the accomplishment of CINC operational missions.
- Provide recommendations for an analytical framework that could be used to assess the military utility of space systems and pass on to WG 2 (as representatives of the modeling and simulation community) for future tool development.

Prior to the workshop, the WG 1 organizers attempted to narrow the "problem" scope by selecting specific key space Mission Areas to focus on. Based on current activities and needs within the various space analysis communities we were working with, the group decided upon Force Enhancement and Space Control. This would presumably allow the workshop participants to concentrate their efforts and provide significant contributions to advancing analysis techniques for these critical mission and sub-mission areas.

Force Enhancement was defined as focusing on providing capabilities to enable or support air, land, sea and space military operations and helping achieve information superiority. It provides the US military with a means of gathering and disseminating highly accurate information to provide forces with situational awareness, effective Command and Control (C2) and maximum force effectiveness. It is comprised of six sub-mission areas: Navigation; Satellite Communications; Environmental Monitoring; Surveillance and Threat Warning; C2 and Information Operations (IO).

Space Control was defined as ensuring the freedom of operation within and through the space medium, while denying its use to our adversaries. It is "chartered" to protect and defend space and is essential to achieving space capabilities as a Force Multiplier. It is comprised of the sub-mission areas of: Space Surveillance; Offensive and Defensive Counterspace; and, National Missile Defense.

Activities

The workshop agenda was intended to focus the participants early on to reach some consensus on the understanding of the problem, important definitions, and potential approaches. To this end, Working Groups 1 and 2 conducted a joint session comprised of several presentations. The concept was to cover the gamut from the "philosophical" to the "practical" in order to stimulate ideas and discussion. These presentations included, *Warfighter Requirements for Space and Computer Network Operations MS&A*; *AFSPC Conceptual Model of the Mission Space*; *A Conceptual Framework for Developing a Structure for Measures of Merit: A Critical Thinking Approach*; *Linking Systems Performance & Operational Effectiveness*; and *Decomposition and Recomposition: Developing an Analysis Framework.* Not only was the subject matter of these presentations diverse, but also the presenters represented a great cross section of government and industry, as well as MORS veterans and "rookies."

This forum proved to be productive as much deliberation was generated. Discussions ranged from differences of opinion about the current state of space MS&A to differences of opinion about definitions to differences of opinion about methodologies and analysis approaches. One of

the points of contention revolved around the appropriateness of a proposed methodology for creating an analysis framework based off of a Strategy-to-Task functional mission decomposition of Joint Vision 2020. As this was one of the key features in the plan for WG 1 (in terms of providing a framework to start with as opposed to creating one from scratch), some additional time was required - once WGs 1 and 2 separated - to discuss the relative merits and problems with this approach. Several examples of this approach as it was applied to a specific problem were presented and discussed. In addition, detailed decomposition documentation was provided to the group. Overall, reaching consensus proved to be somewhat elusive. However, this process was effective as a good point of departure for the "work" portion of the workshop.

The working group members broke into five subgroups to attack the space mission areas (and corresponding sub-mission areas) of Force Enhancement and Space Control. One subgroup also decided to separately tackle IO. The objectives for this part of the workshop were to answer the questions:

- Do we have adequate methods for evaluating the utility of these mission areas and sub-mission areas in an operational context? Are there complete analytical "threads" from bottom to top?
- Do we have adequate methods for representing systems at the appropriate level? Where do they plug in?

What we were looking for from each subgroup was a brief description of the mission area and corresponding sub-mission areas, a description of the technique they used for their assessment, a "decomposition" of the mission area, associated Measures of Merit (MOM) at each level in the decomposition, and whether causal linkages could be identified and perhaps defined between levels. The going-in premise was that if the problem could be dissected into small enough pieces and that these pieces could be evaluated along with their respective interrelationships, we would have accomplished several things: 1) We would have refined and advanced definitions and techniques for determining military utility, specifically for Force Enhancement and Space Control operations and their associated systems, and in so doing, 2) We would have identified those areas where adequate measures and methods exist and those where they do not.

It should be noted that the original objective here was not to advocate methods for evaluating these space mission areas in a vacuum (pun intended), but rather to determine how they integrated into a military utility framework, such as JV2020. The initial concept was to essentially conduct a top-down decomposition of each mission area and then determine how/where it "plugged into" JV2020. However, since we had so much diversity in our group composition, we had an opportunity to explore a variety of avenues. Therefore, each subgroup took a somewhat different approach to look at the availability and applicability of methods to quantify their respective mission areas' contribution to military utility. Following is a synopsis of each subgroups activities and findings.

Subgroup 1 – Force Enhancement 1

This subgroup took on the sub-mission areas of navigation, satellite communications and C2. Their approach to understand and articulate the utility of space-based capabilities on warfare had

three aspects: consider why we have failed in the past; determine what's different now; and, determine a process to go forward. In general, although there have been some recognized successes in the past, many efforts have suffered from either poor selection of metrics, lack of "real" analysis (for a variety of reasons), scenario constraints and "chronic underfunding of modeling and simulation development." However, the members of this subgroup felt that this may change as leadership seems to be more aware of the problems, both political and budgetary, and is expecting a fix.

The process they chose was to consider the validity of the proposed Strategy-to-Task approach and then, for each sub-mission area pick a metric and run a single thread through. This was deemed to be as much as they felt possible in the time frame of the workshop given the magnitude of the problem and their level of subject matter expertise. In terms of the Strategy-to-Task approach, they determined that this was "a very good idea," particularly because considerable work was underway in several DoD organizations using a similar methodology and because it provides for and encourages a common vocabulary.

This subgroup found that analysis methodologies for navigation could be fairly well defined and that a common set of metrics within the context of a common Strategy-to-Task was needed. In addition, they felt that the metrics should be independent of the simulation they would be used in. Analysis of satellite communications impacts noted that virtually all MOEs were affected and should have some communications sensitivity represented in the linkages. Lastly, they determined that C2 should be represented by linkages in the MOE to MOO level of analysis. In general, they felt that communications and C2 are not well represented methodologically in terms of their operational impacts.

Overall, this subgroup decided that not even a perfect Strategy-to-Task framework would "solve" the problem, but it would greatly advance the whole military utility analysis and trade study effort for the entire community. It could be used to focus on where we need to fix models and to establish a common basis for trades of all systems, jointly.

Subgroup 2 – Force Enhancement 2

This subgroup focused on environmental monitoring and surveillance and threat warning. They attempted to strictly follow the proposed Strategy-to-Task process using the JV2020 decomposition that was provided. This subgroup made tremendous progress toward fleshing out the existing decomposition and identifying where these sub-mission areas should be integrated into the process. In so doing they were able to determine where many linkages (i.e., relationships between "elements" in the decomposition and corresponding metrics) existed, however, it was also determined that many of them were not well defined and could not be quantified. This was noted as a deficiency in the current methods and an area for further investigation and/or research.

Subgroup 3 – Space Control and Information Operations

This subgroup tackled the analytical challenges of Space Situational Awareness (SSA) and Offensive and Defensive CounterSpace (OCS/DCS). Their approach was to identify tasks,

measures, and analysis methodologies for these Space Control sub-mission areas, assess the appropriateness and completeness of current methods, and identify areas requiring new methods and analytical approaches. They obtained and reviewed existing documents and found that methods do exist to model certain information superiority operations, such as near earth and deep space surveillance to gain battlespace information of space, however they were unable to access them.

They also determined that analysis methods exist, with supporting models, which allow mission analyses of OCS and DCS. Inputs for these methodologies and models include probability of detection of targets, probability of kill for weapons versus targets, and probability of Battle Damage Assessment (BDA). Outputs include effectiveness (in terms of degradations) against Space-Based ISR, Surveillance, Communications, Navigation and Weather. These degrades are MOEs in their own right, and are linked to campaign models to demonstrate effects to the warfighter and CINC objectives.

They also identified several problem areas, including the linkage of SSA to OCS and DCS. SSA models exist at Cheyenne Mountain and elsewhere, although they didn't know if any are appropriate to support OCS/DCS analyses. Current methods assume SSA. Linkage of OCS and DCS to campaign models is a partial success. Navigation measures and ISR measures are very good for the air campaign, however they felt these measures are not incorporated elsewhere. Communications effects are measurable, but the real effect on sortie generation and ground unit effectiveness must be assumed. Lastly, they decided that current models don't play weather well and that surveillance effects are pretty good with respect to air base operations.

This subgroup had two recommendations regarding analysis methods for Space Control: 1) survey SSA models and determine if any can be used to support OCS/DCS analyses; and 2) develop a dynamic, two-sided, space campaign methodology and model (encompassing two-sided SSA, OCS and DCS play). They felt this would be a good long-term solution for the Space Control Mission Area and that it should be an AFSPC priority.

This subgroup also focused on computer network operations. They followed the Strategy-to-Task process using the JV2020 decomposition that was provided. They refined the existing decomposition and added several tasks and metrics. They also identified some causal relationships, however they found that many of them were not well defined and could not be quantified. This was noted as a deficiency in the current methods and an area for further investigation and/or research.

Subgroup 4 – The "Induction" Subgroup

This subgroup took a unique "bottom-up" approach to evaluating methodologies for space system utility analysis, with the added dimension of doing this for several applications, or "customers" (e.g., Analysis of Alternatives, Requirements Analysis, Quadrennial Defense Review (QDR), etc). Their idea was that different customers were looking for different types of answers. For example the requirements community may have different analysis needs than those making budgetary decisions. Their methodology was to look at a sample of space systems that

are representative of various space missions and are high cost/high interest programs. They then graded these systems against several taxonomies in order to **induce** overarching conclusions. The 3 taxonomies (sets of categories) they chose were:

1. JV2020
2. DPG 03-07/QDR 2001 Force-Sizing Construct
3. DPG 03-07/QDR 2001 Critical Transformation Goals

The JV2020 taxonomy followed the same top-level breakdown as was used in the Strategy-to-Task decomposition; the subgroup evaluated the operational concepts of Dominant Maneuver, Precision Engagement, Focused Logistics, Full-Dimensional Protection, Information Superiority, Joint Forces C2 and Innovation. The Force Sizing Construct taxonomy was broken down into categories of Defense of the US, Forward Deterrence in Critical Regions, Defeating Enemy Efforts in Two Critical Regions, Decisive Defeat in One Critical Region and Small-Scale Contingencies (SSC). Lastly, the QDR Transformation Goals taxonomy categories were Protecting Critical Bases of Operations and Defeating WMD, Assuring Information Systems and Conducting IO, Projecting Power in Anti-Access Environments, Denying Enemy Sanctuary, Enhancing Space Systems, and Leveraging Information Technology.

The grading scheme was intended to identify/score where:

- No direct influence between system and category existed.
- Influence exists; accepted functions relating system performance to "category utility" exist.
- Influence exists; functions relating system performance to category utility were rough.
- Influence exists, but no <u>generally accepted</u> functions relating system performance to category utility exist.

The systems received relatively consistent scores across the spectrum of categories for all the taxonomies examined, with just a few exceptions. This seems to indicate that our current analysis methodologies may be somewhat system-centric. In general, this subgroup found that anything that does communications or information operations is hard to quantify in terms of category utility and the issue must be how to measure the contributions of these functions respectively. Furthermore, they judged deterrence as "red" across the board, which is important if space systems are sized and shaped to provide or support deterrence.

Subgroup 5 – The "Outliers"

This subgroup decided to take yet another approach to accomplishing the workshop objectives. Their background statement asserted that the DoD is transitioning from Warfighters who fight a linear, echeloned enemy requiring intra-communications and local information to theater commanders today who fight a non-linear, non-symmetric enemy requiring inter-communications and global information. Space must be an integral part of this new paradigm. They had a multi-step approach: determine the problem statement based on the customer, establish what space provides to the warfighter (force enhancements), cross walk the Old Paradigm with the New Paradigm enabled by space, and determine the methodology needs to

perform space analysis. Lastly, they surveyed subgroup members on desired space analytical capabilities based on analysis experience, both personal and ancillary.

The subgroup then formulated several problem statements: 1) We cannot adequately quantify military utility of space within the decision cycles (POM cycle, QDR decision cycle, CINC decision cycle, Warfighter decision cycle, Acquisition cycle, Wargame assessment cycle); 2) The current space methodology is configured for the Old Paradigm; and, 3) The space methodology is not linked to the fight. Another issue they noted was that we've always had C4ISR, but have never convincingly quantified it. Now, we are not able to measure the value-added of space in C4ISR. Furthermore, the subgroup contrasted the old paradigm with the new paradigm, asserting that we are moving from attrition-based to effects-based analysis, from theater-focused systems to an agile global architecture, from echeloned to non-echeloned/network centric, from intra- to inter-theater command, from service oriented to joint forces and coalitions, from linear (FEBA) to non-linear, and from scripted to dynamic command and control.

The next step was to identify methodologies that addressed these problems. The subgroup put these into three categories: 1) Methodology that can be adapted to the full spectrum of conflict, including scenarios (DPG/CPG), integrated priority lists, master plans, and decisions; 2) Methodology that quantifies the decision space between services in the space enabling arena, including CINC decisions, Joint/OSD decisions, and Theater Warfighter decisions; and 3) Methodology that is based on the new paradigm. This methodology would have the flexibility to change things in the tool that have heretofore been hard-coded, have interfaces between service M&S (near term), space capability embedded in M&S (long term), include post processing products that improve space capabilities analyses in the new paradigm, and have automated quick setup capabilities. This was contrasted with their view of how we conduct space analyses today, which typically consists of using several types of system or engineering level simulations and manually inputting their performance/contributions into higher level models (e.g., Corps or Division).

Lastly, this subgroup posed the following survey question: *Based on your analytical experience (personal or ancillary), what do we in DoD need in terms of new methodology, changes/modifications to current methodology, or combinations of models/tools?* The answers to this question were: 1) We need space system analytical representation in military models/tools. The reason for this is they felt it is easier to gain acceptance by DoD decision makers if the representation of the space system is embedded in the analytic model and it assists in normalizing space for the warfighter. 2) We need to determine how best to include space representation in our military suite of analytical tools, including mathematical models, visualization, constructive simulations, wargames, experiments and political-military exercises.

Observations

Among the first lessons we learned was that the definition of "utility" of space systems was difficult to pin down and participants showed up with different perspectives. This can be attributed to several things. It depends on what "level" of conflict we're dealing with: strategic, theater, operational or tactical. It also depends on whom we're answering the question for: that is Study Director, CINC or SECAF.

One potential way to address this problem could be "inspired" by the "Induction" Methodology used by one of the subgroups. The JV2020 taxonomy scoring process could serve as a first level "filter" to determine which systems (and associated functions) have adequate analysis methods as applied to the JV2020 Operational Concepts. Methods and subsequently models could then be developed to address any deficiencies. These tools could then be used for Military Utility Analysis, Trade-studies, AoAs and Cost-Benefit Analysis. The Force-Sizing and QDR taxonomy scoring processes could be used in the budgetary analysis processes and to illustrate areas where additional analytical emphasis is necessary. The analysis community could then try to identify areas where synergy exists between the categories and, as analytic methods improve, use them to feed the others.
Another finding was that language differences are big. This is especially true between services. For example an Air Force Mission level simulation has a different meaning for the Army. An Army Mission could be represented in a Brigade, Battalion, Division, and/or Corps level model. This poses many problems when attempting to define analysis methodology "hierarchies". For this reason, it is evident that there are still many stovepipes between the Services in the way they conduct analyses and "Joint" analysis methodologies don't appear to be evolving very well. As an example we noted that certain space operations or functions provided by space systems could be seen to have an impact on the Air Campaign in an Air Force model, however, corresponding impacts were not seen in the maneuver portion of that model. This type of occurrence is not unique and makes it difficult to determine whether a particular space system is being represented correctly (across the board) in many current methodologies.

The working group also noted that many capabilities that have existed (e.g., communications and C4ISR) are enabled differently from space, however we haven't had good methods for representing them before. It was suggested that work is being done, for example, in the communications arena that should get pulled in.

Finally, many comments were made that approaches such as the one we attempted had been done before. In fact, it was discovered that a significant amount of work already existed that would be of great benefit to fleshing out our methodologies. In general, however it seems that there has been insufficient follow-through and much duplication of effort. We discovered that many capabilities exist, but in disparate pockets and not enough cross-pollination. This appears to stem from the fact that there is no single organization with the "charter" to advance the state of the art with a "God's Eye View."

Conclusions

When the group came back together, the overall conclusions were that there are adequate methodologies currently in existence for analyzing some of the specific sub-mission areas, such as navigation and some aspects of space control. However, other mission areas, including communications, command and control, environmental monitoring, and surveillance and threat warning were not very robust or, in some cases, not very well understood, particularly with regard to their operational impacts. In those areas, there are some associated MOMs but not much exists to link the various measures within levels of evaluation, across mission areas, or into

other media. Furthermore, some models were found to have (at least) partial capability but tended to be manually intensive and are in need of more dynamics and automation.

Another conclusion was that there are several other applications that are not well addressed (e.g., OOTW and Transformation). Furthermore, we need wargaming models, particularly for Space Control, and models with the right TTPs represented. In addition, we need better strategic effects modeling, specifically to look at the deterrence aspects of space systems. Lastly, the existence of stovepipes between the services' analysis approaches and within the space community further complicated the capability to do thorough and objective analyses, particularly for systems-of-systems evaluations. The overarching synopsis was that we needed to determine what the Joint Analyst needs to properly and adequately analyze Space Support to the Warfighter within the applicable decision cycle(s).

Overall, we found that the objectives and methodologies for the workshop were sound but too ambitious for the allotted time frame. We felt we made significant progress and achieved some of our goals. We identified several areas where adequate methodologies exist at various levels of analysis, as well as other areas that we don't yet have our arms around.

Recommendations

Three steps that the group thinks would help relieve the Space Community's analytical methods challenges include:

(1) That the ASAC support model and data repositories and a lessons learned program to avoid "reinvention of the wheel." This may help to advance the state of the art for the methodologies discussed.

(2) That USSPACECOM continue to advocate the need for joint analysis and work to break down the existing stovepipes. This would help ensure that space systems and the mission areas they function within are adequately represented across all aspects of conflict.

(3) That MORS assist USSPACECOM in stressing jointness and address the need for basic research in many of the mission areas to quantify the effects' basis of the utility of space systems.

Working Group 2: Analytic Tools

The space community's models and simulations have grown around the commonly accepted definitions of attrition warfare. Space capabilities' modeling has for the most part been limited to astrodynamic code or models that address specific space-related topics, such as navigation jamming. Recent observations and questions raised by the Defense Science Board, the Space Commission Report, and the Kerr report call attention to the adequacy of space M&S and ask the question: Do we need improvements in analytic tools? The answer from most space and MS&A stakeholders is: Yes!

The Defense Science Board Task Force Report titled "Space Superiority" dated September 1999 said:

> "...the nation currently lacks the necessary modeling and simulation capabilities required to fully and appropriately assess the "military utility and worth" of national security space systems.

and

> "...this deficiency undermines our ability to correctly balance the funding priorities between space systems, weapons systems and other support junctions to maximize US military force combat effectiveness. The DSB Task Force recommends that a higher priority be placed on the modeling and simulation efforts focused on assessing the "military utility and worth of space" and that the Commander, US Space Command be assigned the responsibility for developing and operating such capability."

The Space Commission Report Findings (page 78), January 11, 2001 said:

> "To support exercises, wargames, and experiments, DoD must develop and employ modeling and simulation tools based on measures of merit and effectiveness that will quantify the effects of space-based capabilities."

The underlying and common themes of each of these identified that there are decision makers or supporters (at various levels throughout DoD) who are placing increased emphasis on military utility of space systems and the impact that these space systems make to joint military ops and homeland defense, yet DoD is ill-equipped to articulate these impacts. Other problems which many throughout the space community have observed are:

- A perceived lack of credibility in our tools.
- No dedicated funding for space analysis requirements.
- Procedural problems with stovepiping and data/tool sharing.
- An ability to model space capabilities at many levels a failure to make an impact at the AFROC/JROC level where campaign results are important to decision makers.
- A lack of unity of command throughout or across the different components of the DoD space community, a lack of a space MS&A champion.
- The growth of the USSPACE mission to include Computer Network Operations (CNO).
- Recognition that even if a certain armed service has wonderful representation of certain space capabilities in its model it goes for naught if that representation is not captured commensurately in other services' models.
- That the services and DoD agencies need to break down walls between their data repositories and share model data.
- A differing ability to represent space functionality in our models which varies by the level of aggregation of the model.
- Flatly not representing space in campaign models very well while space-specific and some engagement-level models are adequate.

- Models at different levels of aggregation have different space functionalities to represent and different MOMs which they must portray.

In planning for this workshop, MORS considered top-level questions such as: determining the best approach to developing models that will capture the unique capabilities and limitations of space-based systems; whether or not a new set of space-focused Lanchester equations should be developed; whether or not current models should be linked together to form system-to-engagement-to-theater-to-campaign analysis capabilities; and, determining how analytical tools can be updated to include valid representations of space systems, together with their contributions and limitations.

Purpose

Leading into the workshop, the working group leadership had fine tuned the original focus more toward identifying current tools and models and determining their suitability for addressing the array of space capability questions required in a potential DoD Space M&S Toolkit. The a priori steps they identified included identifying gaps in the current set of tools in use throughout the space community, and defining those analytic tools needed to implement the analytical methods defined by WG 1 (Analytic Methods) during the course of the workshop, and determining if new tools are required, or if current tools can be adapted and updated to address the needs of the space community.

The working group membership gathered jointly with WG 1 and agreed upon a common top-level purpose to: **Improve DoD's Space MS&A Tools.**

Working Group 2 reviewed their group's incoming assumptions and proposed purpose, and revised it to form WG 2's component of the joint top-level goal as:

> **Recommend a deliberate process to identify and assemble a set of credible tools to represent space capabilities and functionality throughout the joint community.**

The subgoals that support and enable this primary goal are: identify Space and CNO capabilities and functionality; build a process to identify a set of analytic tools that accurately represent space assets; and, build a process to manage this *DoD Space Analysis Toolkit.*

Assumptions

There are several assumptions that affect how the working group derived its purpose statement above. We observed that the problems of representing space capabilities don't exist at all levels of aggregation. There are many tools at the engineering level that work admirably, and there is even a very aggregated application reportedly in use on the Joint Staff that suffices for broad brush questions. The strategic planning community has also made significant strides in analysis tools for 25-year integrated investment analysis. The analysis community's current capabilities focus on systems-level representations. The tools that primarily need a space injection (for military utility analysis and the ability to articulate that utility) are the campaign-level models,

and links between mission-level and theater/campaign models. Finally, there are a large number of space tools (and smaller number of CNO tools) that do exist and can be sifted to populate a toolkit

Findings

The working group's primary finding, which will be supported by observations later in this report, is that the DoD Space Community needs a coordinated, minimal-but-sufficient set of modeling and simulation tools for analysis. This set should minimize redundant capabilities and development expense, should be commensurate, and results should be importable and exportable. The working group proposes the following seven-step roadmap to DoD for building such a tool set.

Proposed Toolkit Construction Process

7. Admit/remove tools as required

6. Build new tools as required

5. Prioritize needs, build investment plan

4. Derive shortfall list (requirements minus current toolkit)

3. Assess current tools w ability to meet criteria (admit to toolkit)

2. Identify community's current tools

1. Build Toolkit Taxonomy Criteria

d. Identify levels of aggregation/detail of tools

c. Identify evaluation measures (for decision makers) tools must address

b. Identify space systems' capabilities to be included in toolkit

a. Identify types of decisions toolkit will support (ops planning, acquisition, AoA, strategic planning, budget, etc)

Step 1. Establish a taxonomy (multiple scales with criteria for each) for organizing and characterizing the tools to admit to the toolkit, and which could also be used in the future, once the toolkit is established, for an analyst to assess the toolkit's contents and extract from the toolkit the tool most applicable to an analyst's need.

Step 1a. Characterize the types of decisions models this set may be used to support. The first descriptive classification to divide candidate tools into involves the overall purpose of the tool. This is a high-level categorization which would divide tools into categories of the types of questions the tool is used to answer. These categories could include: acquisition, analyses of alternatives, force structure, military worth, planning (operations and strategic), training, AFROC/JROC-level prioritization, requirements, operations, logistics, communications, business processes (planning, programming, budgeting), etc.

Step 1b. Identify space systems' capabilities to be included in toolkit. This descriptive classification catalogs all the space system capabilities a given model plays, as well as all space system capabilities the customer analysis community requires to be able to play. These categories could include: the accepted space mission areas of Force Application; Force Enhancement; Space Support; Space Control; and, CNO. It could also include as their component functions: surveillance and reconnaissance; situational awareness; Real-Time Information (RTI); mission planning, weaponeering, navigation and targeting; command and control; data fusion; correlation/ID; and, information superiority.

As the unified and component space commands develop a Conceptual Model of the Mission Space (CMMS) for Space (CMMS-S), that community-wide statement of key space capabilities could be merged with the existing statement of capabilities described in the previous paragraph, or the CMMS-S could replace that existing statement.

Additionally, a new entire element of the taxonomy could grow from a development of the Universal Joint Task List (UJTL) and linking the tasks of the UJTL to and through the service task lists and the component space command tasks. This descriptive classification would list all basic tasks which need to be accomplished at some point along the spectrum from Strategic National all the way down to specific tactical/field responsibility.

Step 1c. Identify measures of merit which each capability to be included in the toolkit can represent. Construction of these sets of evaluation measures will vary for each tool for decision context (Step 1a), and they will also vary by level of aggregation of the tool. That is, the MOM can be a Measure of Effectiveness (MOE), a Measure of Performance (MOP), Measure of Utility (MOU), or Measure of Outcome (MOO). These sets will categorize the outputs a particular tool can provide an analysis. They will be part of the overall classification matrix and will also be used in conjunction with Space Capabilities and Decision Types.

Step 1d. Identify scope of tool (level of aggregation). The tool will be classified by the level of specificity of its input and outputs, the scope of the types of questions it addresses and the types of answers it provides. The levels could be strategic, campaign, theater, mission, engagement, system, engineering component, etc.

Step 1. Summary: Application of Taxonomy
Steps 1a-1d constitute a basic taxonomy for classifying models so they may be placed in a logical and organized fashion into a toolkit. This taxonomy furnishes a set of criteria to an analyst for searching the toolkit to determine which component from the toolkit satisfies an analyst's need. In the long term, the toolkit manager or managing group can add other discriminators to expand taxonomy and broaden the way one classifies/assesses models. This taxonomy provides an approach that ensures DoD-level relevance, tool fidelity consistent with decision context, and it supports traceability of requirements for a specific study/analyses.

Step 2. ID Community's Current Tools
In constructing the toolkit, the "builder" (individual, organization, or committee assigned the responsibility of constructing the toolkit) must identify candidate models from the M&S universe

and make a cursory assessment of model's ability to contribute meaningful outputs toward an analysis. If a candidate model clearly can't contribute or is below the level of detail the toolkit will be designed for, the builder will exclude it from admission consideration. If the candidate model has possible useful contributions, go to Step 3.

Step 3. Assess Candidate Tools for Admission
The toolkit builder will assess all the capabilities of each candidate tool against all of the criteria of each dimension of the toolkit taxonomy to determine where it should reside in the overall compartment of the toolkit. If the candidate tool possibly satisfies a need/niche in the taxonomy matrix, the builder will grade the candidate against all other tools which possibly satisfy that need/niche to determine admissibility. The builder must balance admitted models so that the greatest number and most important needs/niches are represented across all the taxonomy categories. There will be situations where a candidate model may not be the best tool to satisfy given needs (i.e., other tools are better suited), but the candidate model will have unique capabilities where no other models exist, and therefore, while somewhat redundant, the candidate model will still be admitted.

During the assessment process, the builder will need to identify or include other selection criteria such as cost, VV&A pedigree, amount/accuracy/currency of data the model requires; the amount of maintenance the model requires, the model's compliance/interoperability with existing instructions, toolkits, etc.

Step 4. Derive Shortfall List
After the initial toolkit is constructed, the builder will compare requirements (results of Step 1b) with identified capabilities (Steps 2 and 3) to produce a list of shortfalls.

Step 5. Prioritize and Plan
The space MS&A community must then identify which shortfalls are most important, which ones must be addressed/reconciled first, and a timeline for addressing the remainders. This will require the space M&S community to organize itself in such a way as to non-confrontationally build an M&S investment plan, to be able to obtain and allocate funding, establish a process which addresses and minimizes conflict about responsibility, ownership, etc. There is a highly successful precedent for this kind of self-organization within DoD after which the space community could model itself, and that is the Joint Technical Coordinating Groups (for Aircraft Survivability and for Munitions Effectiveness) chartered and annually funded by the services' three-star Joint Aeronautical Commanders Group (JACG).

> "It's amazing what can be accomplished when you don't care who gets the credit"
>
> - Various (including Ronald Reagan)

Step 6. Build New Tools
Under the aegis of some space "champion" or coordinating body, the space M&S community must implement the Step 5 plan by assigning non-duplicative, coordinated, synchronized responsibilities for developing the new capabilities.

Step 7. Admit/Remove Tools
The space M&S community must identify a process for adding newly developed (or discovered) tools after the baseline kit is built and for removing tools whose presence is superceded by development of joint level tools or those which becomes obsolete. There should be an iterative process of periodic review.

The construction of this proposed process was heavily influenced by presentations from MAJ Bill McLagan, USSPACECOM/AN, on *Warfighter's Requirements for Space and CNO Modeling, Simulation and Analysis*; Colonel Kent Lambert, AFSPC/XPY (Deputy Director of AFSPC Space Analysis Center), on *Thrust Areas for Space Analysis Modeling*; Dr Larry Rainey, Aerospace Corp., on *A Conceptual Framework for Developing a Structure for Measures of Merit: A Critical Thinking Approach* and *A Process Of Determining Measures Of Merit Across Multiple Programs*; Dr Walter Perry, RAND, on *Linking Systems Performance and Operational Effectiveness - A Framework for Assessing the Impact of MOPs on Combat Outcome*; Steve Friedman, Veridian, on *Decomposition and Recomposition: Developing an Analysis Framework*; Maj Mike Doyle, AF/XOCA, on *AF Standard Analysis Toolkit Development*; and, Don Murrell, AFSPC/XPYA, *Model Selection Process for Ground Moving Target Indicator Analysis of Alternatives*.

Observations

During the conduct of the workshop, our working group made observations on matters specifically focused on the question at hand, but also on parallel and associated M&S issues.

First, we note that the AF has had a fairly successful experience in creating their Standard Analysis Toolkit and is worthy of emulation. We understand that there were limitations in their process, and much has become known since their research and inception in 1997. All their lessons learned are applicable to the need we advocate for DoD. Likewise, the ASAC has had a successful experience in creating a specifically focused set of tools for the Ground Moving Target Indicator (GMTI) and AoA and is also worthy of emulation.

In general, the DoD MS&A community needs better cross representation of space, CNO, air, land and sea capabilities across all its major analyses by ensuring that these domains are represented effectively in their tools for analysis. This leads to the observation that the overall OR community has an information sharing problem. There are many and multiple data sets in existence that have been applied to specific purposes but not advertised to other segments of the community. Similarly, but not necessarily by accident, there are many germane and useful data sets scattered across the intelligence community based on various -INTs which are not made available to the MS&A community. We need to improve cross-INT collection and sharing, and the OR community needs better partnering with the intelligence community. The OR community needs to improve awareness of existing simulation data and procedures and the ability to obtain/share data. One route for addressing these problems is an increased participation in existing M&S and data repositories, and stronger encouragement and participation in populating them with annotated and pedigreed data, which is historically only an afterthought. These observations are summarized below:

- There are an insufficient number of simulation users groups with established configuration management and sustainment procedure.
- The Air Force in particular, and probably DoD in general, needs better training, retention and supply of space ops-experienced analysts.
- In pursuit of the taxonomy above, the community needs to establish a rational basis for tool evaluation. The UJTL-to-task-to-MOM is a suggested approach worthy of research and development. Likewise, development of a detailed and community-accepted space CMMS would pay dividends.
- The OR community needs to stay focused on analysis methods and tools to support DoD transformation process for space and CNO.
- As always, the missing ingredient to the solution is lack of adequate funding to attack these problems head-on. There has been awareness of the magnitude and make-up of these problems in the past, but the previous piecemeal approach to funding and effort has made no headway. There has never been as high a level of spotlight and awareness on the problem as now however. If the community can't take advantage of the high level reviews, statements of need, and expectations by senior leadership that a solution must be obtained, it may never happen.
- In order to be effective at achieving a solution, the community needs a champion to lead, to advocate for significant funding, and for creation of a Joint Technical Coordinating Group (JTCG) for Space akin to the already existing JTCGs for Aircraft Survivability and Munitions Effectiveness.

Recommendations

Many of the Space Community's analytical tool challenges would be alleviated if the DoD Space Community would identify or task an agency to assume role of champion/ Office of Primary Responsibility for the Space MS&A community.

This person/agency could implement/direct/oversee the seven-step process which this working group report is proposing/transmitting, including:

- Identifying/aggregating/advocating/prioritizing/disbursing overall funding
- Providing resources to encourage population and use of M&S Resource Repository
- Forming a joint group (which would include USSPACECOM's Space Users Group [SPUG]) to coordinate M&S technical matters between services/agencies in the space arena which could include coordinating (prioritizing and deconflicting) time and effort applied to model and development, and providing a forum for apportioning model improvement funds on a JTCG-like basis

It would also be useful if the MORS Sponsors and the workshop proponents would:

- Disseminate this proposed process and these observations/recommendations to appropriate offices in their services.
- Channel results of the MORS Information Operations Workshop into the space M&S arena and enduring participants of the Space Workshop.

- Have prominent slot for this workshop's results at the 70th MORSS at Fort Leavenworth. *(Editor's Note: This is done.)*
- Schedule follow-on (annual or bi-annual) Space Issues Workshops with feed to the MORS Symposium (MORSS).
- Suggest that DoD augment the Space Users Group and space MS&A actions throughout DoD.
- Encourage and empower MORSS WG5 to informally carry on these themes and proposals.

Working Group 3: Operational Methods

(Analysis and Satellite Control: Facing the Present, Imagining the Future)

Working Group 3 was chartered to investigate optimization-based improvements to scheduling for the Air Force Satellite Control Network (AFSCN). The working group membership was diverse. It included experts in scheduling optimization at the masters and doctoral level, software developers for the current AFSCN scheduling procedure who were also extremely knowledgeable about current AFSCN operations and scheduling practices, and developers of optimization-based AFSCN scheduling software. The tasking to the working group appeared in two somewhat different forms within the workshop's TOR. The versions were:

"Scheduling optimization methods. The scheduling of a worldwide network of limited resources to meet diverse mission needs (e.g., scheduling time on the antennas comprising the Air Force Satellite Control Network) is currently accomplished manually, using a very time consuming and personnel-intensive method. The scheduling of these ground systems, including meeting prioritized mission requests for satellite command and control contacts, scheduled maintenance periods, software freezes in preparation for launches, etc. is ripe for the application of operations research methods to decrease the personnel requirements and optimize resource scheduling. What specific methods or tools should be recommended to approach this and other similar issues in the space community?"

and,

"Focus on the development of optimization methods that address the operational needs of the space community. Use the AFSCN scheduling problem as a prototype and define the structure for its optimal solution."

So, as when President Kennedy was confronted with two very different messages from Khrushchev during the Cuban missile crisis, the chairs had the luxury of choosing which to answer. This flexibility became important in the course of the workshop. (A member of the Synthesis Working Group did remind the chair of President Kennedy's fate.)

Air Force Satellite Control Network Background

The AFSCN consists of fifteen antennas distributed across eight sites worldwide, as illustrated in Figure 1. These antennas and their associated communication gear allow Air Force space

operators to communicate with a number of US government satellite constellations. These constellations depend on the AFSCN to transmit commands from satellite controllers to the satellites, and receive telemetry data on satellite State of Health (SOH). Some US government satellites have their own dedicated ground stations and do not use the AFSCN. The AFSCN, first operational in 1965, is based on aging technology. While isolated sporadic upgrades have kept it operational, the network is recognized to be in desperate need of major renovation. Scheduling of contacts between antennas and satellites was originally done on long sheets of butcher paper with strips of colored tape representing the duration of the various contacts. AFSCN schedulers used this to build a nearly feasible schedule, and conflicts were resolved in dialog between representatives of the satellites involved. The current scheduling engine is a software implementation of this same method, and thus still depends heavily on human expertise and "face to face" conflict resolution. No formal priorities exist to drive the scheduling or resolve conflicts, though informal de facto priorities are quite evident. For a detailed discussion of the AFSCN, see Gooley [1].

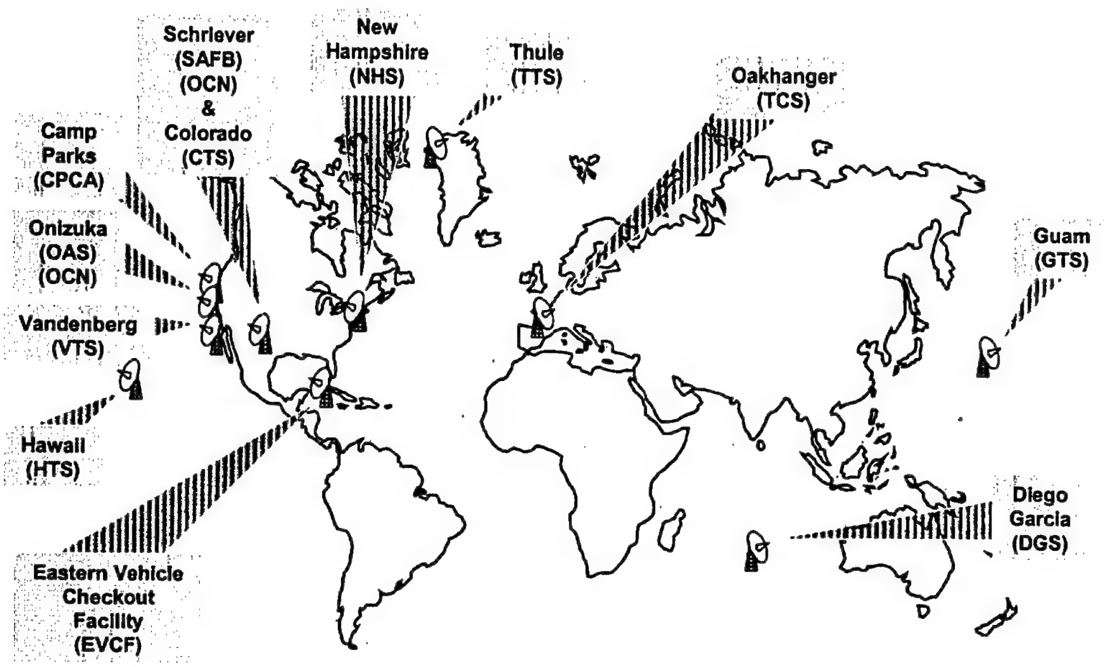

Figure 1. Air Force Satellite Control Network (AFSCN) Site Locations

The future of the AFSCN may involve growing to a Government Satellite Control Network (GSCN). The GSCN would pick up new customers by absorbing current constellation-specific satellite control facilities, servicing new US government constellations, and competing in the commercial satellite control market.

Working Group Agenda

The working group chairs, both optimizers, planned on focused sessions where the optimizers and AFSCN experts worked together to define data sources, model structure, and algorithms,

much in the way OR analysts traditionally work with customers. Adhering to the adage that "no plan survives its first brush with combat," this plan floundered when many of the AFSCN experts voiced the opinion that the current scheduling system needed no injection of optimization to handle the current workload. The system built the schedule on time and resolved conflicts. Some contacts were inevitably dropped from the schedule, but the padding of contact requests by the AFSCN users made the value of these dropped requests questionable.

The working group spent its first day wrestling with this conundrum. The optimizers were incredulous that such an antiquated scheduling process could be made "better" by optimization. The AFSCN schedulers questioned what "better" could mean in light of the current successful scheduling, the lack of formal priorities, and the padded scheduling requests. The first day ended on this frustrating note, though the mixer afterwards helped soothe some of the frustration.

The working group chairs found themselves faced with a dissenting opinion from the loyal opposition in the working group outbrief. The synthesis group, with the job of pulling together all the working group findings into a coherent result, was already taxed to its intellectual limits. The AFSCN working group chairs knew such divergence in their outbrief might push the synthesizers over the edge. So on the second day the working group broadened its discussion of the AFSCN to try to discover what would be necessary for optimization to make a verifiable difference in schedule quality.

The Revised Agenda *"Fall behind early—there's more time to catch up."*

The lack of technology modernization seemed related to the impediments to optimal scheduling and an assumption of causality was tempting. Tales of vintage 286 processors, 19.2 kb transmission rates and antiquated displays feeding a primarily manual scheduling system painted a vivid picture. Was this process beyond help? Obsolete technology is clearly a major issue for the AFSCN no matter what the scheduling methodology, but questions remained. All the scheduling information eventually made it into the system, through manual entry if necessary. Why couldn't optimization take over at that point? Couldn't a scheduling algorithm still help my moving the schedulers closer to the "best" solution before they began conflict resolution?

Unfortunately, we still lacked a definition of "best," and with no priorities assigned to the various requests for satellite contacts, none really existed. The schedulers achieved a feasible schedule while factoring in implicit priorities, recognizing that some customers were "more equal than others"[2]. The lack of formal priorities is key, and points to a larger problem. The problem has analytical aspects but is not an analysis problem *per se*. It involves the central control of the AFSCN, or rather the lack thereof. Certainly there is central control by AFSPC, the 50th Space Wing and the 22nd Space Operations Squadron over AFSCN operations and modernization of their infrastructure. But AFSCN customers are a diverse lot, including satellite owners from throughout and beyond the US Department of Defense. The Air Force has had limited success forcing the users to modernize their ends of the AFSCN infrastructure, so obsolete data formats and glacial transmission rates require continuing support. The AFSCN Executive Council (AEC), chaired by the 50th Space Wing commander, has representatives for most users but lacks the authority to enforce a contentious prioritization scheme for scheduling

and conflict resolution. And a prioritization scheme with any real effect will probably be contentious by definition.

The working group concluded that the real problem was organizational. An overhaul of the organization would allow modernization, prioritization, and yes, optimization. The working group spent the remainder of the second day nailing down the organizational changes that would allow the AFSCN to advance technologically, and the analytical capability needed to guide this advancement.

AFSCN Organizational Changes

In the pre-Space Commission days, the organizational challenge might have been insurmountable, since the AF had no way to exert authority over non-AF AFSCN users. Now, as the executive agent for space within the DoD, the AF should empower the AEC to truly manage and direct the AFSCN. The AEC should have the authority to direct modernization of all aspects of the AFSCN, including user equipment, and the budgetary resources and authority to underwrite this modernization. The AEC should also have the authority to set prioritization policy for satellite contacts. As stated earlier, the lack of formal priorities is a primary reason for the inability to improve scheduling through optimization. The AEC would then be able to investigate prioritization methodologies based on market dynamics, similar to the bidding procedures now used for bandwidth allocations. With coordinated and enforceable priorities, AFSCN schedulers will be far better able to deal with conflicts between customer requests, and an optimization-based automated scheduler will be afforded an objective function attuned to these priorities. Planning for crises and contingencies will also be possible. With planned priority schemes tailored to the critical needs of the nation's senior leadership, the AFSCN will be poised to immediately respond to a wide range of unfolding situations. Finally, and most importantly, the empowered leadership and management advocated here is a necessary condition for the evolution for the AFSCN to the GSCN. Indeed, without the centralized direction and funding of all aspects of AFSCN modernization, contemplation of a GSCN is unwarranted.

Improved Analytical Support to AFSCN Planning

Given the organizational changes just described, the evolution to the GSCN demands thorough analysis of alternative technologies and concepts of operation to support decision makers. The working group now focused on what modeling capabilities would support such analyses. This, as one might expect, was closer to the original charter of the working group and proved much less contentious. The analytical challenges ahead for the AFSCN are not that much different from those of any large network of complex systems seeking to modernize and expand its customer base, and some may be addressed by analysis techniques already used in government and industry. The following is a list of some of the modeling needs the working group anticipated.

Demand Forecasting. The nature and quantity of demand for future AFSCN or GSCN services is uncertain. Growth in the number of government satellite constellations is a given, but the degree of autonomous operation and thus the demand for AFSCN services is unclear. Similarly

nebulous is the likelihood that civil constellations would consider using GSCN for satellite control functions. AFSCN planners will need analytical tools and techniques to study future demand possibilities in order to plan for future network growth.

Capacity Allocation. Given some sense of leadership goals and priorities, analysts need to provide insight into the best use of current or programmed AFSCN resources. Resources include ground and space-based systems, communication capacity and manpower.

Ground Architecture. The future AFSCN or GCN ground architecture will be influenced by leadership directives, actual and projected demand and resource constraints. The implications of choosing one ground architecture over another may be profound, and decision makers will benefit from analytically based studies of the trade-offs associated with different ground architectures.

Service Request Simulation. Analyses of the day to day performance of the AFSCN often require realistic simulation of a stream of service requests from some current, projected or hypothesized customer base. At present this simulated demand is difficult to obtain. A valid means of simulating a range of demands on the network does not exist but is sorely needed.

Cost Estimation. Planners of military force structure know the difficulty of getting good cost estimates of future systems. Technological, budgetary and political volatility all contribute to bias and variance in cost estimation. The AFSCN and GSCN are no exception. Cost estimation tools exist and are in use by the planning and acquisition communities. AFSCN planners should begin building their cost estimation capability as much as possible on proven cost models, and develop further tools as necessary.

Scheduling. Scheduling, specifically optimal scheduling of the AFSCN was the genesis of this working group, and can now be discussed. Analyses of different network configurations will certainly need to generate schedules from the simulated service requests discussed earlier. While computationally complex, AFSCN scheduling has proved tractable for optimization based scheduling software. At least one commercial product exists which can generate optimal or near-optimal solutions based on user priorities and resource constraints. As the resulting schedules are shown to be efficient and effective and the organizational changes discussed above take hold, the door may be opened for the introduction of optimal scheduling to AFSCN operations.

Conclusions

The working group's conclusions about the AFSCN are straightforward. The AFSCN is capable of accomplishing its current mission with little change beyond maintenance and, when necessary, occasional upgrades to its current infrastructure. The software-supported manual scheduling, in the absence of any official prioritization of customer requirements, is similarly adequate. However, if the AFSCN is to evolve into the GSCN and be competitive with commercial satellite control vendors, major organizational changes would help. For example, a central authority derived from the existing AEC could set priorities for customer support, develop modernization efforts, and have the budgetary and bureaucratic authority to enforce all of these. Such an

organizational change would also open the door for better applications of analysis, to support the decision making required to wisely chart the course to the GSCN, indeed to decide if evolution to the GSCN is warranted.

The working group leadership drew further conclusions about the working group process. Analysts in such a situation should be prepared for the possibility that the real problem may not be analytical. In this case, organizational issues superseded the technical issues. Yet the skills possessed by analysts, namely the ability to clearly state the problem, approach it systematically, harness diverse capabilities in a group environment, and communicate compelling results are just as crucial to solving the non-technical as the technical. The working group chair unexpectedly found the facilitation experience gained through certain decision analysis applications was more useful in this case than his much-beloved mathematical programming expertise, arguing for breadth as well as depth in the skill set an analyst brings to bear. Analysts, particularly optimizers take note — in some circumstances the "soft" techniques we sometimes treat with disdain may turn out to be our salvation.

References

1. Timothy Gooley, (paper)
2. George Orwell, *Animal Farm*, Harcourt Brace and Company, 1946.

Working Group 4: Sustainment Methods

The Sustainment Methods Working Group, WG 4, addressed how analytical methods could be applied to assist decision makers in smartly sustaining space ground systems and designing new systems with long-term sustainment in mind. Current methods of ground station sustainment use periodic maintenance activities and emergency/urgent maintenance actions to keep the systems running. In most cases, the use of fault detection, identification and prediction techniques is limited, or non-existent; leaving decisions on upgrades and modifications to the systems to be made on an ad-hoc basis. As with WG 3, the prototype for the problem definition and application was the AFSCN. This was done with the realization that the suggested methods could be applied across the gamut of space ground systems and on-orbit assets.

The AFSCN is composed of 15 antennas at 8 sites used to command and control a wide range of Air Force, DoD, and commercial satellites. The sites are shown in Figure 1 (found in the previous section). The network is aging, with some of its equipment exceeding 40 years of service. Each site's equipment is diverse, and in a different maintenance condition. Over the next 8 years, all the antennas and the core electronics used to control the antennas will be replaced under the Remote Tracking Station (RTS) Block Change (RBC) program. In the meantime, the current antennas must be sustained to ensure uninterrupted operations for the networks users.

The working group objective was to determine how advanced analytical techniques might be applied to guide development and sustainment of space ground systems, including such techniques as failure trending and cause/effects analysis and condition-based maintenance methods. The objectives specific to the AFSCN became:

- How should the advanced analytical techniques be applied in the design of the "new" AFSCN to demonstrate the capability for lights out operations?
- How should the advanced analytical techniques be applied to guide the decision making for sustainment of the legacy equipment?

Current Sustainment Methods

The group started their deliberations with presentations on the current state of the art of AFSCN sustainment. It was during these presentations that the heart of the challenge emerged...the AFSCN's antennas and core electronics will be replaced over the next eight years through which condition based maintenance will be applied and the capability for "lights out" operations will be demonstrated. In the meantime, the current, aging (~40 years old), network of 15 antennas at 8 remote sites and their associated equipment must be sustained.

The original AFSCN sustainment method can best be described as "run to failure"...basically running the antenna and its associated electronics until something failed, then calling in the maintenance team to replace the component. Beginning in the early 1990's, more deliberate means of sustaining the network began to evolve. Some limited fault detection methods were implemented, included such things as monitoring the bus of the control and status processor, allowing some diagnostics when the system crashed. Fault identification included RF waveguide monitoring. Non-destructive testing methods were implemented including the use of thermal cameras and strain gages. Means of failure prevention were put in place, including the capability to measure gear synchronization using a backlash tool. Finally, some failure monitoring and prediction techniques have been put into place including the servo automated test equipment to analyze the drive systems of the antenna control unit; shock pulse testing to conduct ultrasonic analysis on the antenna bearings; and, some limited oil analysis procedures in conjunction with periodic maintenance activities. Future plans call for the continuation and increased focus on a systematic oil analysis program; implementation of a logistics management information system to document and integrate sustainment activities; and, increased use of remote automated monitoring and lubrication systems.

Analytical Tool Review

Armed with an understanding of the current and planned AFSCN sustainment methods, the working group then turned its attention to a review of applicable analytical methods that might be applied to the problem. The methods reviewed included:

- Legacy Logistical Analysis Tools
- Sustainment/Support Optimization
- Prognostics and Health Management
- Condition Based Maintenance and Logistics

Legacy Logistical Analysis Tools. There are a number of logistical analysis tools...mostly focused on the aircraft sustainment/maintenance issue...that with a slightly altered problem definition, could be used to help model the space ground system sustainment problem and

provide decision support. For example, the Aircraft Sustainability Model (ASM) computes optimal spares mixes to meet desired system readiness levels (i.e., A_o). The Readiness-Based Maintenance and Supply (RBMS) model computes optimal mixes of maintenance (repair) and supply (spares) actions for both man-hour and budget constraints to meet desired system readiness levels (i.e., A_o). The "daddy-rabbit" of all logistics models…Logistics Composite Model (LCOM)…is focused on aircraft support and maintenance and models sortie processing including scheduled and unscheduled maintenance activities. The model provides measures of aircraft performance based on specified resource levels (i.e., manpower, support equipment, spares) to help define critical parameters, such as sortie generation rate, manpower or footprint requirements. Although these models are primarily focused on aircraft analyses, with slight tailoring they could be applied to the space system sustainment questions. For example, by calling the scheduled contact between the ground station and an on-orbit satellite a "sortie," the assets at a ground station that are required to conduct a given contact "support equipment," and the spares required to keep the ground station operating the "spares"; an LCOM scenario can be developed that would guide operational and sustainment planning.

Sustainment/Support Optimization. Optimization techniques have been successfully applied in a number of sustainment/support analyses, including: design trades, reliability allocation, and planning for modification/retrofit, spares inventory, maintenance activities, and supply chain optimization. For example, design trades involve determining the optimal design configuration to meet system requirements for a given budget. Reliability allocation involves determining the optimal allocation of reliability requirements to subsystems and components to achieve overall system reliability objectives. Optimization techniques have been applied to determining the optimal combination of system modifications to meet system objectives for a given budget. Optimal spares inventories have been determined considering downtime reductions for a given budget. Optimal maintenance strategies have been developed to maintain a desired level of system performance given an allotted maintenance budget. Finally, optimal inventory levels and production needs throughout a supply chain have been determined to meet varying customer demands. While all the examples presented to the working group had applicability to the problem at hand, and the problem of optimally designing the future AFSCN, the modification/retrofit, spares inventory, and supply chain optimization examples provided immediate benefit toward developing the group's resolution methodology.

Prognostics and Health Management. Prognostics is the capability to estimate the probability of a system failure over some future time interval. The capability to perform prognostics assumes the existence of a system model that would allow the assessment of risk and consequence of system failure. The model uses real-time data from sensors, as well as historical maintenance data, environmental conditions, aging models, etc to characterize the state of the equipment and predict time to failure. A sample prognostics and health management architecture is shown in Figure 2.

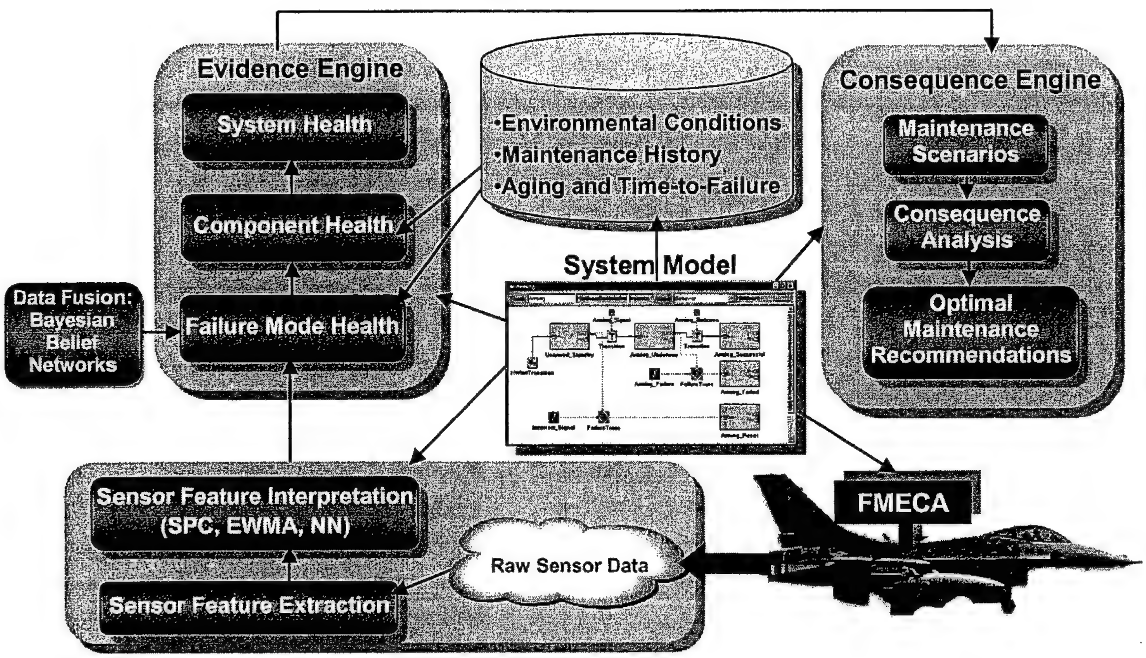

Figure 2. Sample Prognostics and Health Maintenance Architecture

Condition Based Maintenance and Logistics. Prognostics is the "science" behind the concept of condition-based maintenance and logistics. The objective of Condition-Based Maintenance (CBM) is to accurately detect the current state of internal mechanical and electrical systems and accurately predict the systems' remaining useful lives. Thus, maintenance can be performed only when needed to prevent operational deficiencies or failures. The implementation of a CBM program eliminates costly periodic maintenance activities and greatly reduces the likelihood of machinery failures. Condition-Based Logistics (CBL) integrates CBM with an integrated data environment to allow analyses and linkage to supply chain management. As with the PHM system described, the first step in implementing a CBM or CBL program is understanding the physics of failure of the system...understanding the failure mechanisms and cause/effect relationships are the necessary first step.

Recommendation

After the review of the current industry standards and research in this area, the working group recommended a way ahead for implementation of systematic sustainment of the legacy system and incorporation of new methods into the evolving design. The working group recommended a building block approach including analyzing the system and identifying its inherent failure modes, developing methods and algorithms necessary to identify and predict the incipient failures, select a testbed site, implement and iterate. The applicable techniques included condition based maintenance and logistics, prognostics and optimization. The steps to implement the recommended methodology are described in more detail below.

Steps to Implement CBM. The analysis stage of implementing a CBM program begins with identifying the critical systems, or bounding the problem. The subsystems that should be considered at this stage are those that demonstrate low reliability, are testable (i.e., easily

accessible), and, in the AFSCN application, are common across both the legacy and RBC implementation. With the systems identified, a FMECA must be performed to identify the failure modes of the system. In addition to the failure modes themselves, the symptoms of the failure modes must be identified. These failure symptoms will identify the conditions that the sensors must detect, identify the data that must be collected and its associated sampling rate; thus driving the sensor selection and placement decisions. Simultaneously, decision making criteria must be established...what actions will be taken when a given condition is indicated; and a data management scheme must be developed...what information must be archived, displayed or forwarded for further action.

Once the analysis phase is complete, the program can move into its design and prototype phase. During this stage the data requirements and architecture are developed, including such considerations as pre-processing, processing and database design. In addition, the applicable algorithms are developed by which the failure "features" will be extracted from the data, data is fused from multiple sensors, and the diagnostics/prognostics decision making is defined and implemented. The development of the prognostics algorithm, at this point, includes such activities as developing a database/case history library in which is contained historical data, heuristics, environmental and usage conditions, and aging models. Time series data is also collected on the system in order to characterize the relationship between the symptom and the failure and the evolution of the fault trend prior to failure. With the necessary data/information gathered, the prognosticator can be trained and implemented...put to work in estimating remaining useful system life. With the design well in hand, a testbed site is then chosen. For the AFSCN case, the working group suggested the Colorado Tracking Station (PIKE) at Schriever AFB, Colorado due to its proximity to the Colorado Springs area and the station's familiarity with its role as the network's "guinea pig." The sensors are then placed and the data collection and analysis begins in earnest. Once the system is in place and operational, periodic evaluations of its performance will be performed. The design and implementation of the system (i.e., sensor placement, data collection scheme, algorithm tuning, etc.) will iterate until a steady state is reached in which appropriate CBM decisions are being made.

Steps to Implement CBL. Once the CBM system is at steady state, the next logical step is to implement a condition-based logistics program. This involves defining the way the CBM process fits into an integrated data environment...connecting the maintenance data with the supply chain and support network.

Optimization Application. The implementation of prognostics, CBM, and CBL are necessarily a long-term initiative for the AFSCN and the space ground system sustainment community. In the meantime, the optimization techniques presented at the workshop can be readily applied to assist the community with their current decision making challenges. In the AFSCN case, given the immediate need for good day-to-day sustainment decision making and the long-term need to develop a sustainment-ready RBC design the optimization examples provide relief in both areas. First, for legacy system decision aides the mods/retrofit optimization could be used to guide sustainment planning, the maintenance optimization could be used to guide periodic maintenance scheduling, and the spare inventory and supply chain optimization could be used to determine initial sparing levels for major modifications and to periodically reevaluate the sparing levels required at each remote tracking station. The optimization techniques that are applicable for the

RBC planning and design include design trades to determine optimal subsystem redundancy within the system, allocation optimization to determine each subsystem's contribution to availability per unit cost, and spares and supply chain optimization to determine the initial provisioning at the RBC sites.

Challenges

There are a number of challenges to successfully implementing CBM, CBL, and prognostics to the AFSCN or any other space ground system. First, it will be difficult to quantify the cost vs. benefit of implementing the system. Without the ability to quantify the benefits of better sustainment decision making, it may be difficult to find the funding to implement the recommendations. While few would advocate our return to the "run to failure" mode of system sustainment, we are not yet at the crossroads where budgets are freely available to improve sustainment decision making capabilities. Second, linkage of the physics of failure to reliability…the basis for the prognostics methods and algorithms…is an immature science. Within that field, electronic equipment characterization is proving to be especially challenging. Third, the age old question of data availability and validity will have to be addressed. How do we gain confidence in the prognostics without sufficient failure data? How do we relate the failures to the measurements that can be taken with our sensor suite? For example, what is the relationship between crack size and temperature or vibration measurements? Finally, to reap the benefits of an investment in this type of analytical activity, the result should be applied to more than just the AFSCN. However, we have described the necessity to understand the unique the system failure modes and symptoms as the first step in the process. How can this be applied across the family of ground system sustainment activities? What information should be shared across programs and what information is unique?

Conclusion

Working Group 4 focused on what analytical techniques could be applied to the challenge of space system ground station sustainment. Their focus was on the Air Force Satellite Control Network with an eye toward extensibility to other ground station or on-orbit asset sustainment challenges. After a review of the current AFSCN sustainment methods, the group found that the applicable analysis techniques, including failure modes effects and cause analysis, condition-based maintenance/logistics, prognostics, and optimization are not being used. Further, they noted that the challenge for AFSCN is two-fold: sustain the legacy system and implement a condition-based logistics approach for the antenna replacement program. After a review of the applicable techniques, the working group recommended implementation of CBM/CBL, prognostics, and optimization using a building block approach.

Synthesis Group

The Synthesis Group for this Workshop was an exceptionally experienced one by virtue of its distinguished membership: Past President Roy Rice, President Elect Ted Smyth, Vice President for Meeting Operations Anne Patenaude, Fellow of the Society Gene Visco, and longtime MORS member and career Air Force Analyst Colonel Jerry Diaz. Greg Keethler was privileged

to chair this distinguished group and brought to the task his background as a career Air Force Analyst, an analyst in industry, and an experienced MORS Workshop participant and organizer.

Role

The role of the Synthesis Group is to look across all of the working groups to find themes, notable differences, and other lessons that transcend working group boundaries and represent common findings. The task was a particular challenge for this Workshop because two of the four working groups were looking at very broad, high-level issues regarding methods and tools, while the other two were each focusing on a particular problem with a particular system. Working Group 1 (Analytical Methods) and Working Group 2 (Analytical Tools) were closely aligned in tackling the challenges in assessing the impact, benefits and effects of space systems from a warfighter's perspective. Working Group 3 (Operational Methods) focused on how OR methodologies could be leveraged to improve space operations, using the Air Force Satellite Control Network as the venue, and Working Group 4 (Sustainment Methods) tackled sustainability issues using the same venue.

Common Themes

For a while there, it seemed that the only common theme was that all the working groups met in Colorado Springs! However, continued observation and consultation amongst the Synthesis Group members revealed that some common themes emerged after all.

First, there are many needs within the space operations arena to which OR methods could be applied and result in some benefit. No synthesis group member observed any problem being discussed that seemed to defy traditional OR methods. It seems that for a variety of reasons, well-described in Mark Reid's Outbrief of Working Group 2, there simply has not been sufficient focus to apply them with widespread success in the past.

This can be at least partly attributed to the fact that space operations and the analysis thereof are relatively new as compared with those in the three more terrestrial realms of air, ground, and sea. This "newness," although not an inhibitor in the working groups, was indeed a backdrop to all of them. Space decision makers have not been accustomed to analytical inputs to their decision processes, and the analysis community has not particularly focused on Space systems and effects over the years. The resulting dynamic has been to slow applying analysis to this "new" area for quite some time, and it is this negative inertia that members of the groups have experienced. Many of the participants in the workshop were space operations practitioners who were being exposed to OR techniques and their potential benefits for the first time, and as such, exhibited such views — e.g., "we are already optimal."

A related finding that emerged from observing the working groups is that none of the problems posed by operating in the space environment seem to offer the need for new and unique OR methods — in other words, the problems faced in applying analysis to Space Operations is not a "special" case; it's simply not a well-traveled trail at this point in time.

Given that Space offers a veritable "smorgasbord" of analysis opportunities and needs, it is not surprising that the working groups focused on providing an "approach" or "roadmap" for

pursuing solutions in their respective areas. This is in some contrast to the statements of the majority of plenary speakers, who alluded to a virtual "Space Analysis Crisis" and appealed to the workshop to provide answers to immediate needs. Practically speaking, it is much more productive for analysts to spend a few days comparing notes, experiences and perspectives to arrive at a "roadmap" than to answer the expectation that they will somehow all agree on a "point solution" in the same period of time. So although there are no specific recommendations addressing many of the plenary speakers' concerns, each of the working groups identified a course, that if pursued, should provide specific methods, tools and approaches for the problems at hand.

Finally, a common theme in each of the working groups was that within them were a variety of constituencies, each with their own concerns, needs and perspectives on just what the Space Community's Analytical Challenges are and how to go about meeting them. In this respect, the workshop was like all others.

Obstacles and Hurdles

The working group participants faced a number of common obstacles and hurdles as they tackled their respective issues. As is always the case, there is an initial period consumed by achieving a reasonably common understanding of the problem. This was most apparent in the Working Groups 3 and 4, wherein some elements persisted for some time in insisting there was no problem at all.

The previously cited "different constituencies" and the "newness" issues served to hinder progress in some cases, but, in the end, all the working groups overcame these and progressed toward a roadmap. Underlying all of these, however, were organizational issues that exacerbate the coherent application of OR methodologies to space operations issues. In particular, some key organizations were not represented, and there were organizational issues that were central to solving the fundamental problem — most evident in Working Group 3 but present in all of them.

Finally, the fact that space operations has not historically valued the contributions of analysis pervaded many of the working group discussions. "They'll never sign up to that," or words to that effect, were somewhat commonly heard, and in some cases, were sufficient to prevent full exploration of potentially fruitful ideas.

Roads not Traveled

The Synthesis Group noted a number of "roads not traveled" as the working groups deliberated. Again, there were no specific answers to the plenary speakers' requests to meet urgent needs. None of the working group chairs took a tack toward that goal, realizing full well that such a large diverse group in just a few days was unlikely to agree on such specifics.

Reference was made several times in the Plenary Session to "Space and Computer Network Operations (CNO)" as though they go hand-in-hand and share the same or at least similar analytical challenges. There was some recognition in Working Group 2 that CNO has some of its own unique analytic challenges, but for the most part, these were not pursued further. Space operations seemed to offer more than enough challenges in and of themselves for the groups to

deliberate and discuss. Similarly, reference was made in the plenary session to interoperability issues, but none of the Synthesis Group members observed any significant working group discussion on this topic.

Finally, only one of the working groups made an attempt to dissect the traditional space mission taxonomy (Space Control, Force Enhancement, Force Application, and Space Support) into component parts to determine the analytic challenges associated with them. This terminology, though convenient and appropriate for segmenting the space mission, does not necessarily clarify the analytic challenges, nor is it commonly known and understood in the analysis community. More effort to map these terms into more commonly understood analytic frames of reference may have been fruitful.

Recommendations

The Synthesis Group's observations led it to make some overarching recommendations that transcend the boundaries between the working groups. First, it is clear that the application of OR techniques to Space Operations problems can benefit from the various assets that MORS has to offer. Certainly, there has been a working group on the Operational Contribution of Space Systems at the summer MORS Symposium for a number of years — indeed, there were 16 papers presented last year. But analysts interested in space should work to inject more papers into other working groups, such as Logistics, IO/IW, MOE's, AoA's, etc, so that space becomes more of a "mainstream" thought process in the analysis community — like air, land and sea have become over the years. It is not yet second nature for most analysts to work space considerations into their theater or campaign level analyses, whereas for the other employment arenas, it has been second nature for many years. Similarly, the MORS publications offer an excellent venue to garner more visibility for the analytical challenges of space.

Second, the Synthesis Group felt it important to emphasize the benefits of space analysis enthusiasts participating in the appropriate users groups for campaign and theater level models, and seeking as much space representation as possible in Joint Wargames, Exercises and Experiments. Again, over time, with sufficient persistence and focus, incorporating space considerations and capabilities should eventually become second nature.

Third, one way to introduce space-related issues into the analytical mainstream more quickly is by focusing more on the capabilities and functionalities enabled by space-based systems, rather than the fact that they "come from Space." Usually, there is already some accounting for the types of capabilities offered from space (communications, navigation, observation, etc). The space "twist" might be that there's more of it, it's better, or it's good only for certain periods of time due to "orbitology" considerations. Mainstream analysts can relate more easily to these functionalities and their associated "twists" than just a blanket term identifying them as "space capabilities."

Finally, as was pointed out earlier, the breakdown of space into four mission areas is illuminating in describing the missions associated with the space realm, but is not particularly helpful in applying analysis to the associated issues. The Synthesis Group recommends that to the extent possible, space analytic issues be couched in conventional terms rather than this unique space mission taxonomy—again, to attract the analytic mainstream to these important issues.

A Final Question

All of this led the Synthesis Group to pose the following question regarding the challenge posed by the plenary speakers:

> Is the issue really determining the impact of Space, or, is the real issue one of ensuring that our analytic methods comprehensively account for ALL of our military capabilities (air, ground, sea AND space) and their implications, for whatever purpose — planning, acquisition, force structure, etc.?

Stated another way, must we process warfare through our conventional analytic tools and methods that account for air, land and sea, and then superimpose yet more or separate analyses to account for the "unique" contributions of space, or, can we find a way to integrate the analysis of warfare in all four realms? The Synthesis Group believes, after observing the deliberations of the working groups, that the needs articulated by the plenary speakers are ultimately best served by the latter approach, and we believe the roadmaps laid out in the four working groups will lead to that end.

MILITARY OPERATIONS RESEARCH SOCIETY

MORS Workshop:
Tackling the Space Community's Analytical Challenges

Acronyms

AEC	AFSCN Executive Council
AF	Air Force
AFROC/JROC	US Air Force Requirements Oversight Council/ Joint Requirements Oversight Council
AFSCN	Air Force Satellite Control Network
AFSPC	Air Force Space Command
AoA	Analysis of Alternatives
ARSPACE	United States Army Space Command
ASAC	Air Force Space Analysis Center
ASM	Aircraft Sustainability Model
BDA	Battle Damage Assessment
C2	Command and Control
C4ISR	Command, Control, Communication, Computers, Intelligence, Surveillance and Reconnaissance
CBL	Condition-Based Logistics
CBM	Condition-Based Maintenance
CINCS	Commanders-in-Chief
CMMS	Conceptual Model of the Mission Space
CMMS-S	Conceptual Model of the Mission Space for Space
CNO	Computer Network Operations
DoD	Department of Defense
DPG/CPG	Defense Planning Guidance/ Contingency Planning Guidance
DSB	Defense Service Board
FEBA	Forward Edge of the Battle Area
FMECA	Failure Modes Effects And Cause Analysis
GAO	General Accounting Office
GMTI	Ground Moving Target Indicator
GSCN	Government Satellite Control Network
ID	Identification
INT	Intelligence (type)
IO	Information Operations

IO/IW	Information Operations/Information Warfare
ISR	Intelligence, Surveillance and Reconnaissance
JACG	Joint Aeronautical Commanders Group
JTCG	Joint Technical Coordinating Group
JV2020	Joint Vision 2010
LCOM	Logistics Composite Model
M&S	Modeling and Simulation
MOE	Measures of Effectiveness
MOM	Measures of Merit
MOO	Measures of Outcome
MOP	Measures of Performance
MORS	Military Operations Research Society
MORSS	Military Operations Research Society Symposium
MOU	Measure of Utility
MS&A	Models, Simulations and Analysis
OCS/DCS	Offensive and Defensive CounterSpace
OOTW	Operations Other Than War
OR	Operations Research
OSD	Office of the Secretary of Defense
PHM	Prognostics and Health Management
POM	Program Objectives Memorandum
QDR	Quadrennial Defense Review
RBC	Remote Block Change
RBMS	Readiness-Based Maintenance and Supply
RF	Radio Frequency
RTI	Real-Time Information
RTS	Remote Tracking Station
SECAF	Secretary of the Air Force
SOH	State of Health
SPUG	Space Users Group
SSA	Space Situational Awareness
SSC	Small-Scale Contingencies
TOR	Terms of Reference
TTP	Tactics, Techniques and Procedures
UJTL	Universal Joint Task List
US	United States
USCINCSPACE	Commander-in-Chief, United States Space Command
USSPACECOM	United States Space Command
VV&A	Verification, Validation and Accreditation
WMD	Weapons of Mass Destruction

MILITARY OPERATIONS RESEARCH SOCIETY

MORS Workshop:
Tackling the Space Community's Analytical Challenges

Terms of Reference

Background and Subject Definition
US Space Command combines Air Force, Army, and Navy space components to provide space-based support and combat capabilities to the warfighting Commanders-in-Chief. The support is currently focused predominantly in the areas of communication, navigation, meteorology, surveillance and reconnaissance. Although no current combat capabilities are provided directly from space, the future is ripe to exploit space for "gaining and maintaining the high ground". Some of the current combat capabilities being explored by the space community are space based radar and laser platforms, common aerodynamic vehicles and conventional ballistic missiles that would carry various payloads in and through space for precision strike. These current and future capabilities would benefit from a broad range of analytical support, defining the associated doctrine, exploring relevant tactics, comparing operational concepts, and assuring sustainment over the lifetime of the envisioned systems. The proposed MORS Workshop will focus a select group of analysts and decision-makers to help define these space community challenges; survey current approaches, methodologies, models, tools and databases; identify gaps in the existing analytic capabilities; and propose workable solutions to fill these gaps and support the needs of the warfighter.

1. Goals and Objectives

USSPACECOM and the services' space components are key elements of the nation's military force structure. The Space Commission, the military's scientific advisory communities, and a number of independent study groups have suggested increased emphasis and investment in space capabilities. To ensure current capabilities are appropriately leveraged as well as to help provide a framework for any future changes, the analytic community should be prepared to help answer a broad array of questions unique to this community. These questions include:

- Analytical Methods. What methods and approaches are available to quantify the benefits space offers to CinCs conducting a broad array of operational missions? Stated differently, what does space bring to the fight?

- How can the benefits of the *information* provided by space systems such as unimpeded communication, precision navigation, and near-real time global weather forecasts be quantified in theater or campaign-level analysis?
- What are the unique contributions of space systems? How can the benefits of *missions* provided or supported from space be quantified and balanced or traded against those same missions performed by terrestrial or airborne platforms?

- Analytical Tools. How can analytical tools be updated to include valid representations of space systems, together with their contributions and limitations?
  - The analysis community's models and simulations have grown around the commonly accepted definitions of attrition warfare. Space capabilities' modeling has for the most part been limited to astrodynamic code or models that address specific space-related topics, such as navigation jamming. What is the best approach to developing models that will capture the unique capabilities and limitations of space-based systems? Should a new set of space-focused Lanchester equations be developed? Should current models be linked together to form system-to-engagement-to-theater-to-campaign analysis capabilities?

- Operational Methods. Whereas many of the operations of military units are well defined and steeped in traditions, those of the space components are evolving and are in the early stages of development. Many of the tools that are the norm for the operations research community have not been embraced within the space operations community.
  - Scheduling optimization methods. The scheduling of a worldwide network of limited resources to meet diverse mission needs (e.g., scheduling time on the antennas comprising the Air Force Satellite Control Network) is currently accomplished manually, using a very time consuming and personnel-intensive method. The scheduling of these ground systems, including meeting prioritized mission requests for satellite command and control contacts, scheduled maintenance periods, software freezes in preparation for launches, etc. is ripe for the application of operations research methods to decrease the personnel requirements and optimize resource scheduling. What specific methods or tools should be recommended to approach this and other similar issues in the space community?
  - Status tracking and reporting. The problem of identifying, tracking, and reporting the status of diverse networks of systems at a meaningful level to senior decision-makers in order to successfully advocate for adequate funding levels is an issue facing the space operations, acquisition, and sustainment communities. What methods, such as aggregation, time-series analysis, and reliability, maintainabilty, and availability (RMA) analysis should be suggested to help address these issues and successfully provide results to senior decision-makers?

- Acquisition and Sustainment Issues. Many of the ground systems associated with space operations are approaching, or have exceeded, their design life and are providing challenges to the maintenance and acquisition communities to sustain the systems in an operational status.

- Failure trending methods and failure modes effects and cause analysis. The failure modes of space systems' ground equipment are not well understood, documented, analyzed, or predicted. How might methods provided by failure trending and failure modes effects and criticality analysis (FMECA) or other methods be applied to these systems to help predict impending failures and more adequately plan for maintenance and upgrade programs?
- Conditioned based maintenance methods. Standard maintenance methods consist of periodic preventative maintenance activities and time-of-need maintenance activities to correct deficiencies and system outages. In many cases, the periodic maintenance activities induce more problems than they cure. Maintenance conducted at the point of failure typically involves mission-impacting down time while the system is repaired and/or while parts are procured. Condition-based maintenance involves developing measurements and associated rule-bases that provide an indication of impending failure modes. What analytic methods could be applied to the space ground system sustainment issues to increase operational availability while decreasing overall life cycle costs?

2. Approach

The proposed MORS Workshop...**Tackling the Space Community's Analytical Challenges**...will be organized into four working groups and a synthesis group to address the issues discussed above. The meeting's approach is described in the sections below.

a. **Working Group Chairs and Co-Chairs.** The chairs and co-chairs of the working groups, along with their contact information, are identified in Table 1 below.

Table 1 Working Group Chairs and Co-Chairs

NAME	PHONE	EMAIL	Position
Col TS Kelso	(719) 554-9801	ts.kelso@peterson.af.mil	Workshop Chair
Lt Col Suzanne Beers	(719) 556-2829	suzanne.beers@cisf.af.mil	Technical Chair
Steve Friedman	(937) 476-2509	steve.friedman@veridian.com	WG#1 Chair
Capt Jeff DelVecchio	(310)363-0768	Jeffrey.delvecchio@losangeles.af.mil	WG #1 Co-Chair
Iris Prueitt	(256) 955-3570	Iris.prueitt@smdc.army.mil	WG #1 Co-Chair
MAJ Bill McLagan	(719) 554-5122	Bill.mclagan@peterson.af.mil	WG #1 & #2 Co-Chair
Mark Reid	(719) 651-8855	mreid@ara.com	WG#2 Chair
Tom DeLaCruz	(719) 637-6224	Tdelacruz@scitor.com	WG#2 Co-Chair
Dr. Steve (Flash) Gordon	(407) 208-5776	Steve.gordon@afams.af.mil	WG#2 Co-Chair
Dr. Lee Lehmkuhl	(719) 572-8307	leel@mitre.org	WG#3 Chair
Lt Col Steve Baker	(719) 333-4405	steve.baker@usafa.af.mil	WG#3 Co-Chair
Lt Col Suzanne Beers	(719) 556-2829	suzanne.beers@cisf.af.mil	WG#4 Chair
Maj Brent Barber	(719) 556- 2817	brent.barber@cisf.af.mil	WG#4 Co-Chair
Greg Keethler	(505) 816-6382	gkeethler@ara.com	Synthesis Chair
Col Jerry Diaz	(719) 333-4470	jerry.diaz@usafa.af.mil	Synthesis Co-Chair

b. Working Group Focus. Described below are the areas of concentration for each of the working groups.

Working Group #1 Analytical Methods
Chair: Steve Friedman
Co-Chair: MAJ Bill McLagan
Co-Chair: Capt Jeff Delvecchio
Co-Chair: Iris Pruett

Identify current analytical methods and approaches and determine suitability for defining space's contribution to the warfighting effort...both at a theater and campaign level. This group will work to define space system Measures of Performance (MOPs) and Measures of Effectiveness (MOEs) and their linkage into the "standard" Measures of Outcome (MOOs) used by other theater and campaign analyses. Determine if new analysis methods (i.e., such as some new form of Lanchester equations) are needed, or simply slight modifications of current methods to address how best to quantify the contributions of space capabilities to the accomplishment of CinC operational missions.

Working Group #2 Analytical Tools
Chair: Mark Reid
Co-Chair: MAJ Bill McLagan
Co-Chair: Tom DeLaCruz
Co-Chair: Dr. Steve Gordon

Identify current tools and models and determine their suitability for addressing the array of space capability questions required in a DoD Space M&S Toolkit. Identify gaps in the current set of tools in use throughout the space community and define those analytic tools needed to implement the analytical methods defined by WG#1. Determine if new tools are required, or if current tools can be adapted and updated to address the needs of the space community.

Working Group #3 Operational Methods
Chair: Dr. Lee Lehmkuhl
Co-Chair: Lt Col Steve Baker

Focus on the development of optimization methods that address the operational needs of the space community. Use the Air Force Satellite Control Network (AFSCN) scheduling problem as a prototype and define the structure for its optimal solution.

Working Group #4 Sustainment Methods
Chair: Lt Col Suzanne Beers
Co-Chair: Maj Brent Barber

Focus on the development of failure mode cause and effect analysis and condition based maintenance activities that address the sustainment challenges faced by the space acquisition and

sustainment communities. Use the AFSCN as a prototype and suggest applicable methods to apply to their sustainment issues.

Synthesis Group
Chair: Greg Keethler
Co-Chair: Col Jerry Diaz

The synthesis group will bring together the work of the 4 working groups and develop the overall recommendations from the analysis community to the space community.

c. **Meeting Location.** The workshop will be conducted at the Aerospace and Mitre facilities, located in the Atrium II building at 1150 Academy Park Loop, Colorado Springs, Colorado.

3. Agenda

Table 2 highlights the top-level schedule for the three-day workshop.

Table 2 Top-Level Workshop Schedule

	Tuesday 26 February 2002	Wednesday 27 February 2002	Thursday 28 February 2002
Morning	**Plenary**	**WG Session**	**WG Prep for Outbriefs**
Lunch	**Orientation in WG**	**Lunch Speaker**	**WG Prep for Outbriefs**
Afternoon	**WG Session**	**WG Session**	**WG Outbriefs**
Evening	**Mixer**	**WG Chair Hot Wash**	**WG Chair Documentation**

4. Attendees

The working group chairs are in the process of determining the appropriate membership for each of their respective working groups and providing the information to the MORS office, who will provide invitations to those individuals.

5. Products

Because the working groups are somewhat diverse, a single product form or format will not be appropriate for all the working groups. Discussed below are the products that each group will generate.

WG#1: Analytical Methods… Provide suggested operational metrics and associated linkages for quantifying the warfighting contributions of space systems. Provide recommendations for an analytical framework that can be used to assess the military utility of these systems. This framework may be focused on only one specific "concept", such as Space Control or Space Force Enhancement. Provide recommendations to the modeling and simulation community (via WG#2) for tool development.

WG#2: Analytical Tools...Provide a general process for building a DoD Space Toolkit composed of a minimal and spanning set of applications (not necessarily limited to M&S) that include valid representations of space systems and are credibly usable for analysis.
WG#3: Operational Methods...Provide the basis for an optimal solution for the AFSCN scheduling problem. The product should be provided in such a way that it could be used as the basis for a specification for an automated system that would implement the solution.
WG#4: Sustainment Methods...Provide suggested methodologies for implementing condition-based maintenance, predictive analysis, etc. into operational use by the sustainment community.

6. Milestone Table

D-270	Initiate Concept Paper	Initiator	Complete
D-210	Select tentative dates	Initiator, SMCC, VPMO, EVP, VPA	Complete
D-180	Provide "For Comment" draft of Concept Paper to Sponsors, VP(MO) and other interested organizations and individuals for review.	MORS Office	Complete
D-170	Actively solicit technical *PHALANX* articles relevant to the special meeting topic. Goal is to have technical articles in *PHALANX* appear in the issue just preceding the special meeting.		N/A
D-150 (5Oct01)	Develop TOR from Concept Paper.	Initiator, SMCC, MORS Office	In-work
D-120 (4Nov01)	Circulate final draft TOR to MORS Office and Proponent(s) for concurrence and to other Sponsors and organizations for information.	MORS Office	
D-90 (4Dec01)	Approve TOR, Program Chair, budget and fees.	Executive Council	
D-85 (9Dec01)	Mail ACP, if appropriate and publicize event.	MORS Office	
D-80 (14 Dec)	Select organizations to be invited and prepare letter inviting nominations.	Chair/Co-chairs	
	Select WG or Session Chairs	Chair/Co-chairs	Complete
D-75 (19Dec)	Mail invitations to nominate.	MORS Office	
D-60 (3Jan02)	Select read-ahead material	Chair/Co-chairs	
	Submit nominations or requests for applications.	Nominating Organization	
D-50 (6 Jan)	Select invitees	Committee	
D-45 (11 Jan)	Assign nominees to working groups or sessions.	Committee	
	Mail invitation, WG assignments	MORS Office	
	Provide read-ahead materials and releases to MORS Office.	Committee	
D-40 (16 Jan)	Mail read-ahead materials	MORS Office	
D-17 (8 Feb02)	Pre-registration, security clearances due at MORS Office.	Invitees	
26-28 Feb 2002	Conduct special meeting.	Chair/Committee	
D+30 (3Apr02)	Brief Sponsors	Chair	
D+60 (3May02)	Submit After-Action Report.	Chair	
D+90 (3Jun02)	Complete written products.	Committee	
D+120 (3Jul02)	Approve written products.	Pubs Committee	
D+150 (3Aug02)	Review approved products.	Proponent(s)	
D+180 (3Sep02)	Distribute approved products.	MORS Office	

7. Proponents

The space community's analytical challenges are rapidly gaining interest within the Air Force and DoD analytical communities, as was evidenced at the 1 August 2001 stand-up ceremony of the Air Force Space Command Space Analysis Center. During that ceremony, Lt Gen Roger DeKok, AFSPC/CV, emphasized the need for solid analytical footings for the decisions that the services are making with respect to space forces. Simultaneously, the MORS Sponsors have maintained a generic topic addressing space for the last two years as part of their future special meetings topic list. The forum is sorely needed to bring together members of the analysis and space communities. The analytical community has wrestled with understanding the space medium well enough to quantify "what space brings to the fight" and the space community has wrestled with the application of the appropriate analytical methods to solve their operational needs.

The proponents for this workshop are:
Lt Gen Roger DeKok, Vice Commander, Air Force Space Command
Dr. Jacqueline Henningsen, Director, Air Force Studies and Analyses Agency
Mr. Vince Roske, The Joint Staff (J-8)

8. Planning and Organizing Committee

Shown in Table 3 are the individuals who are serving on the workshop organizing committee.

Table 3 Organizing Committee

NAME	PHONE	EMAIL	Position
Brian Engler	(703) 751-7290	evpmors@aol.com	MORS Exec VP
Natalie Kelly	(703) 751-7290	morsvpa@aol.com	MORS VP for Admin
Dr. Tom Allen	703-578-2773	tallen@ida.org	MORS President
Dr. Roy Rice	256-726-2038	Roy.rice@tbe.com	MORS Past Pres
Anne Patenaude	703-312-2322	apatenaude@logicon.com	MORS VP, Mtg Ops
Jack Marriott	703-633-8300	Jmarrio3@csc.com	MORS Spc Mtg Chr
Lt Col Peter Puhek		peter.puhek@peterson.af.mil	Aerospace Fac POC
Aerospace Security			Aerospace Sec POC
Dr. Lee Lehmkuhl	(719) 572-8307	leel@mitre.org	Mitre Facilities POC
Mitre Security			Mitre Security POC
CDR Timothy Hobbs		timothy.hobbs@hq.navy.mil	N81 POC
Col TS Kelso	(719) 554-9801	ts.kelso@peterson.af.mil	Workshop Chair
Lt Col Suzanne Beers	(719) 556-2829	suzanne.beers@cisf.af.mil	Technical Chair
Steve Friedman	(937) 476-2509	steve.friedman@veridian.com	WG#1 Chair
Capt Jeff DelVecchio	(310)363-0768	Jeffrey.delvecchio@losangeles.af.mil	WG #1 Co-Chair
MAJ Bill McLagan	(719) 554-5122	Bill.mclagan@peterson.af.mil	WG #1 Co-Chair
Iris Prueitt	(256) 955-3570	Iris.prueitt@smdc.army.mil	WG #1 Co-Chair
Mark Reid	(719) 651-8855	mreid@ara.com	WG#2 Chair
Tom DeLaCruz	(719) 637-6224	Tdelacruz@scitor.com	WG#2 Co-Chair
Dr. Steve (Flash) Gordon	(407) 208-5776	Steve.gordon@afams.af.mil	WG#2 Co-Chair
Dr. Lee Lehmkuhl	(719) 572-8307	leel@mitre.org	WG#3 Chair
Lt Col Steve Baker	(719) 333-4405	steve.baker@usafa.af.mil	WG#3 Co-Chair
Lt Col Suzanne Beers	(719) 556-2829	suzanne.beers@cisf.af.mil	WG#4 Chair
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Col Jerry Diaz	(719) 333-4470	jerry.diaz@usafa.af.mil	Synthesis Co-Chair
Maj Brent Barber	(719) 556-2817	brent.barber@cisf.af.mil	WG#4 Co-Chair
Greg Keethler	(505) 816-6382	gkeethler@ara.com	Synthesis Chair
Col Jerry Diaz	(719) 333-4470	jerry.diaz@usafa.af.mil	Synthesis Co-Chair

9. Administrative Section

Meeting Dates: 26-28 February 2002
Meeting Location: Aerospace & Mitre Facilities, Atrium II, 1150 Academy Park Loop; C.S., CO 80910
MORS Hotel: Sheraton Colorado Springs Hotel; 2886 S. Circle Drive; C.S., CO 80906; (719) 576-5900
Fee: US Federal Government: $200; All Others: $400.
Attendance: Limited to 120
Security Classification: Secret